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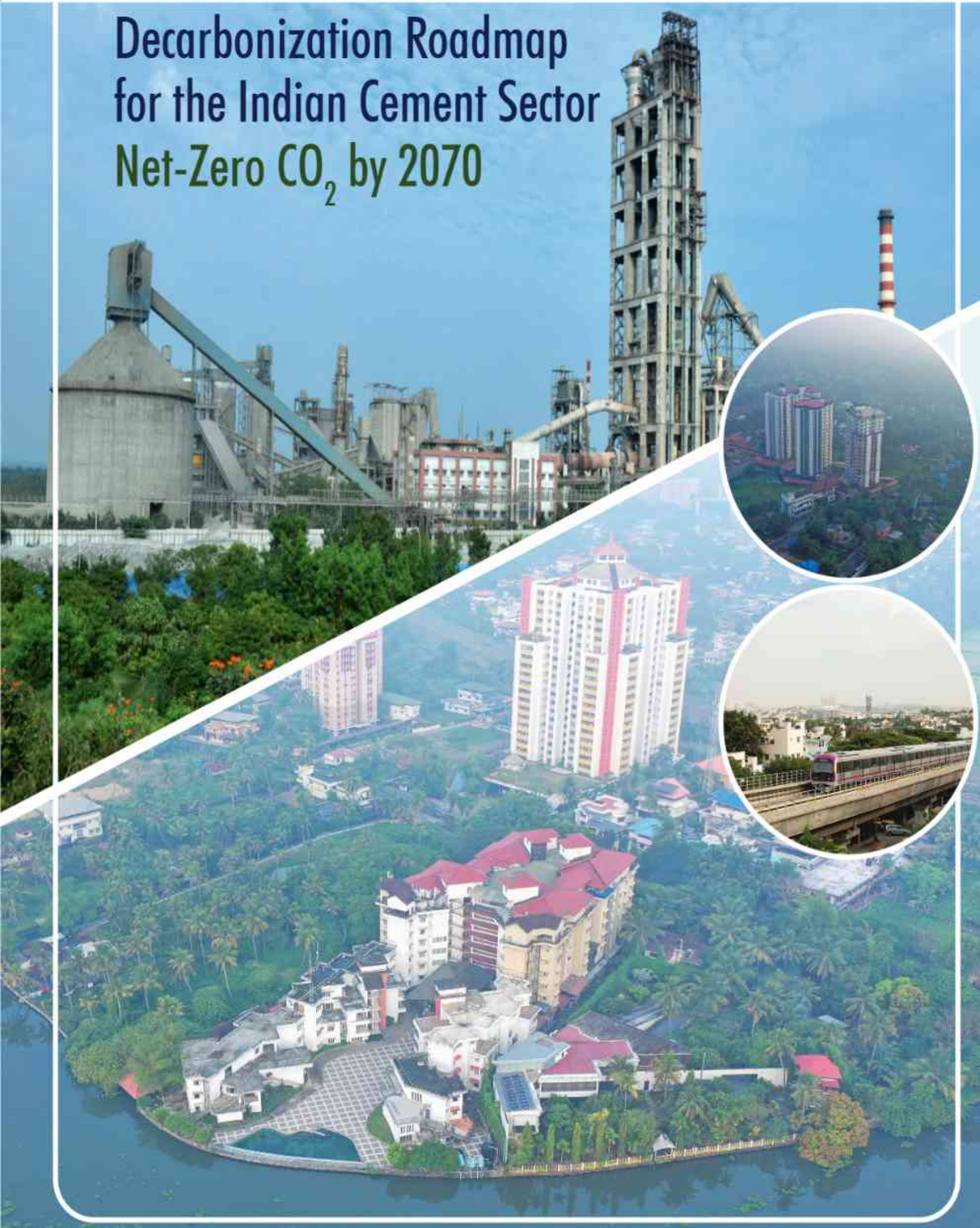
Decarbonization Roadmap for the Indian Cement Sector

Net-Zero CO_2 by 2070



Decarbonization Roadmap for the Indian Cement Sector:

Net-Zero CO_2 by 2070

gcca India (Global Cement and Concrete Association)

THE ENERGY AND RESOURCES INSTITUTE
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Team

Taskforce Members

JSW Cement Limited	Mr Manoj Rustagi (Lead) and Ms Monika Srivastava
Dalmia Cement (Bharat) Limited	Mr Anupam Badola
Orient Cement Limited	Mr P Sreenivasa Raju
HeidelbergCement India Limited	Mr Vimal Jain and Mr Gulshan Bajaj
JK Cement Limited	Mr Ajai Kumar and Mr Brajesh Sharma
MyHome Industries Limited	Mr K N Rao
UltraTech Cement Limited	Mr Suresh Patil and Mr Raju Goyal

Member Company Representatives

ACC Limited and Ambuja Cements Limited	Mr Ashwin Raykundalia
Birla Corporation Limited	Mr Ajay Tiwari
India Cements Limited	Mr Dakshinamoorthy S
JK Lakshmi Cement Limited	Mr Kanish Singh
Nuvoco Vistas Corp. Limited	Mr Ramesh Warke (till Dec 2024) and Mr Sanjay Joshi
Ramco Cements Limited	Mr Ravichandran C
Sagar Cements Limited	Mr Anji Reddy
Shree Digvijay Cement Limited	Mr Satyabrata Sahoo and Mr Milan Trivedi

Key Stakeholders

ECRA	Mr Dennis Behrouzi and Mr Jens Romeike
GCCA	Dr Andrew Minson
LCCF	Mr Vijay Kulkarni
SED fund	Mr Sivaram Krishnamoorthy

GCCA India

Mr Kaustubh Phadke, India Head
Ms Pashmin Dee, Manager-Sustainability
Ms Samanvaya Reddy Bethi, Executive-Sustainability
Ms Yashi Upadhyay, Asst Manager-Sustainability (till April 2024)

TERI

Mr N Vasudevan, Senior Consultant
Ms Taruna Idnani, Project Manager
Ms Sonali Vohra, Research Associate (till March 2023)
Mr Girish Sethi, Senior Director (Reviewer)

Message From Chair, GCCA India

As we stand at the intersection of climate action and industrial innovation, the decarbonization of the cement industry has emerged as both a vital responsibility and a significant opportunity. The cement sector is fundamental to India's economic growth and infrastructure but also contributes to almost 7% of our national greenhouse gas emissions. With our nation's commitment to achieving net-zero emissions by 2070, the cement industry must play an instrumental role in reaching this target.

The India-specific roadmap for the cement and concrete sector is an effort for the same. The GCCA India Decarbonisation roadmap for the Indian cement sector aligns with the Government of India's goals of net-zero emissions by 2070 and includes an interim target for 2047 (Viksit Bharat). The roadmap has been developed as part of The GCCA Net Zero Country Roadmap Accelerator Program. This initiative assists national cement and concrete industries in aligning with the GCCA's 2050 Net Zero Global Industry Roadmap, published in October 2021 before COP26 in Glasgow.

We are proud to partner with The Energy and Resources Institute (TERI) in developing this roadmap. This collaborative journey has included the formation of a task force comprising members from all GCCA India member companies. Key milestones of our effort have included data collection through questionnaires, focused discussions with RMC manufacturers, precast companies, and others, during the stakeholder meetings held in Mumbai and Delhi. The roadmap has incorporated insights from research institutes like the Indian Institute of Technology (IIT) and the Central Building Research Institute (CBRI).

I would like to extend my gratitude to the GCCA India task force members, the European Cement Research Academy (ECRA), and TERI for their invaluable contributions. I am also thankful to the Cement Manufacturers' Association (CMA) for their feedback and review of our roadmap.

While the Indian cement sector has made significant progress over the past two decades—transitioning to dry processes, adopting renewable energy, implementing Waste Heat Recovery Systems (WHRS), and increasing the production of blended cement—we are now aiming even higher with the integration of advanced technologies such as Carbon Capture, Utilization, and Storage (CCUS), green hydrogen, and increased alternative fuels and raw materials (AFR).

Our aspiration to achieve net-zero CO_2 by 2070 in the Indian cement and concrete sector will require policy support and financial incentive mechanisms for the industries from the government, including policy on Green Public Procurement (GPP), to accelerate the transition. The roadmap progress will be reviewed every 5 years. This roadmap serves as a guiding document in our aspiration to be a decarbonized cement sector by 2070.

Parth Jindal
Chair – GCCA India
Managing Director – JSW Cement

Message from Chief Executive Officer, Global Cement and Concrete Association

Cement and concrete are essential for our modern world—for building the resilient communities and sustainable infrastructure that our people and planet need. Our materials will continue to be increasingly necessary for global development, as our global population grows and urbanizes.

As India continues its rapid economic and social progress, cement and concrete will be crucial to its ambitions. The global GCCA is proud to have many leading Indian cement companies as its members, helping to shape the global response to the crucial issue of our time—climate change.

In 2021, the GCCA launched its 2050 Net Zero Roadmap, becoming the first global heavy industry to set out the levers and detailed pathway to full decarbonization. Our members are already demonstrating strong action on a range of decarbonization levers.

As India itself steps up to be a global leader, whether it's in engineering, science, technology and business, I am very pleased to see a national commitment from our sector in India.

While the global GCCA Cement and Concrete Industry Roadmap for Net Zero CO_2 is at the concrete level with a net zero target by 2050, the India-specific roadmap focuses on 2070 to align with the Government of India's Net Zero CO_2 target. However, we fully recognize that India's cement industry decarbonizing pathway (just like in other countries) can be accelerated with active policy support from the government, and this is what our member companies are working towards.

Many of India's leading cement companies, who are also global GCCA members, are working to the much nearer target of 2050. However, to fully unlock our industry's decarbonization efforts, we need effective policy support across a range of levers. From helping to stimulate demand for low carbon cement and concrete, to supporting the use of non-reusable and non-recyclable societal waste being safely treated and used as alternative for fossil fuels in our kilns. We need backing for the use of supplementary cementitious materials, supporting circularity in the built environment, and both recognizing and supporting the important role that technologies such as carbon capture use and storage can play in industrial decarbonization in the years ahead.

When policymakers provide the right market conditions and policy enablers, significant CO_2 reductions are achievable. Strong partnerships between industry and government are vital for our world. GCCA and our colleagues in India stand ready to work together to build the sustainable world of tomorrow.

Thomas Guillot

GCCA CEO

Message from Director General, The Energy and Resources Institute

The cement industry is intricately woven into the fabric of our economies and societies. India is the second-largest producer of cement after China. The emphasis on infrastructure and housing sectors will further increase the demand for cement in the coming decades. India's cement industry has positioned itself as a leading sector in implementing energy efficiency measures as well as adopting renewable energy technologies. Today, the Indian cement plants stand out as the epitome of environmental consciousness exemplified through their commitment to all aspects of sustainable development be it in terms of enhanced use of alternative fuels and raw materials, increased use of supplementary cementitious materials, or adoption of waste heat recovery based captive power plants. Indian cement sector, however, remains as one of the largest emitters of carbon dioxide, mainly attributed to process related emissions and use of fossil fuels.

In line with India's commitment to be a net-zero economy by 2070, the Indian cement industry is actively gearing up to chart out a pathway to decarbonization. The Energy and Resources Institute (TERI) is proud to partner with the Global Cement and Concrete Association (GCCA), India in help developing an India-specific roadmap for the Indian cement sector. I would like to express my gratitude to all the industry stakeholders, specifically the GCCA India Task Force members who have contributed towards the development of this roadmap. The Indian cement industry today is on the threshold of a new era wherein the focus has to move beyond energy efficiency and renewable energy to include aspects such as material efficiency, circularity, cleaner fuels, and carbon capture. My best wishes to the cement industry as they embark on the path of climate neutrality.

Dr Vibha Dhawan

Director General, TERI

सचिव
भारत सरकार
विज्ञान एवं प्रौद्योगिकी मंत्रालय
विज्ञान एवं प्रौद्योगिकी विभाग
Secretary
Government of India
Ministry of Science and Technology
Department of Science and Technology

प्रो. अभय करंदीकर
Prof. Abhay Karandikar

01st March, 2025

MESSAGE

At the Department of Science and Technology (DST), we are committed to nurturing a science, technology, and innovation ecosystem that is cutting-edge, collaborative, inclusive, and aligned with India's national aspirations. Our goal is to build a sustainable, resilient nation, working towards the realization of **Viksit Bharat by 2047**.

We would like to extend our congratulations to GCCA India and TERI for publishing the Decarbonization Roadmap for the Indian Cement Industry: Net Zero CO2 by 2070, with an interim target set for 2047—a critical milestone in India's journey towards sustainable development.

This roadmap provides a comprehensive strategy for achieving net-zero CO2 emissions by 2070, integrating technological advancements, policy interventions, and financial incentives essential for the decarbonization of the Indian cement industry. The document highlights the next 23 years as a pivotal "Period of Action", focusing on the path leading to 2047, a year that marks the realization of India's aspirations for a Viksit Bharat.

Given that the cement industry contributes around 6% of India's GHG emissions, this roadmap represents a significant step forward. It underscores the sector's commitment to reducing emissions and advancing towards sustainability, aligning with India's broader climate goals and international commitments.

A key component of the roadmap is Carbon Capture, Utilization, and Storage (CCUS), which is vital for achieving decarbonization in the cement sector. To support this effort, DST is implementing a pilot project on CCUS technologies in the Indian cement industry. A special call for proposals issued in June 2024 has already led to the selection of projects that will provide valuable insights to inform future policies for large-scale implementation.

In addition, DST is collaborating with leading research institutions across the country to explore innovative solutions such as low-carbon cement and 3D printing technologies, further accelerating the sector's transformation.

We are confident that, with continued technological innovation, targeted policy support, and adequate financial incentives, the Indian cement industry will successfully achieve net-zero CO2 emissions by 2070, contributing significantly to both national and global climate objectives.

(Abhay Karandikar)

Technology Bhavan, New Mehrauli Road, New Delhi - 110016
Tel: +91 11 26511439 / 26510068 | Fax: + 91 11 26863847 | e-mail: dstsec@nic.in | website: www.dst.gov.in

Foreword

Technological advancements and innovations are at the core of the National Council for Cement and Building Materials (NCB). At the NCB, we are making significant contributions to the advancement of low-carbon and sustainable technologies and materials in the cement and concrete industry.

We are delighted to provide our inputs for the development of the 'Net-zero CO_2 roadmap for the Indian cement and concrete industry', a collaborative effort spearheaded by GCCA India on behalf of the Indian cement and concrete companies. The cement and concrete sector plays a vital role in India's infrastructure development, and its continued growth is critical for our nation's progress. As the cement industry contributes 7% of anthropogenic CO_2 emissions globally, the Indian cement industry is proactively transforming itself to face the challenge of decarbonization. The Indian cement industry is also playing a commendable role in the implementation of a circular economy framework in our country by utilizing industrial and other wastes like fly ash, slag, phosphor gypsum, FGD gypsum, hazardous waste, refuse-derived fuel, biomass, etc.

NCB firmly believes in collaborative efforts to achieve the goal of green and sustainable cement industry. This roadmap, developed through extensive stakeholder consultations, fosters a spirit of cooperation between industry, government, and research institutions. By working together, we can unlock the potential of new technologies, promote best practices and create an enabling policy environment to expedite the transition towards a net-zero future.

The roadmap highlights a clear path for the cement and concrete industry of India and is targeted to achieve net-zero emissions by 2070 keeping in line with the Government of India's (GoI) Net Zero 2070 goals. It is a testament to the industry's commitment to sustainable development and its willingness to embrace innovative solutions like Carbon Capture and Utilization. The roadmap considers the unique challenges and opportunities faced in the Indian context, making it a valuable resource for all stakeholders.

The roadmap serves as a blueprint for action. It identifies key milestones, technological advancements, and policy interventions needed to achieve our collective vision. NCB is committed to supporting the Indian cement and concrete industry in its decarbonization journey. By implementing the recommendations outlined in this roadmap, we aspire to build a more sustainable and resilient future for generations to come.

Dr L P Singh

Director General

National Council for Cement and Building Materials (NCB)

Preface

We are pleased to present the Net Zero CO_2 Roadmap for the Indian cement sector. This roadmap aligns with the Government of India's goal of achieving Net Zero CO_2 by 2070, with an interim target set for 2047 (Viksit Bharat).

This document has been developed as part of the GCCA Net Zero Country Roadmap Accelerator Program, which helps national cement and concrete industries align with the GCCA Cement and Concrete Industry Roadmap for Net Zero Concrete, published in October 2021 prior to COP26 in Glasgow.

The GCCA global member companies have committed to net zero CO_2 in accordance with their place in the value chain. GCCA India and TERI, in collaboration with the broader sector, prepared the India sector roadmap according to the GCCA methodology to to be in accord with the Indian government.

Individual companies in the Indian cement sector remain committed to advancing their net zero CO_2 initiatives ahead of schedule, and the roadmap is designed to support, rather than hinder, these ambitions.

This document serves as a sector-specific roadmap for India, aligning with the Government's (GOI) targets. It fully supports the ambition to reach net zero before 2070, with robust government policy support.

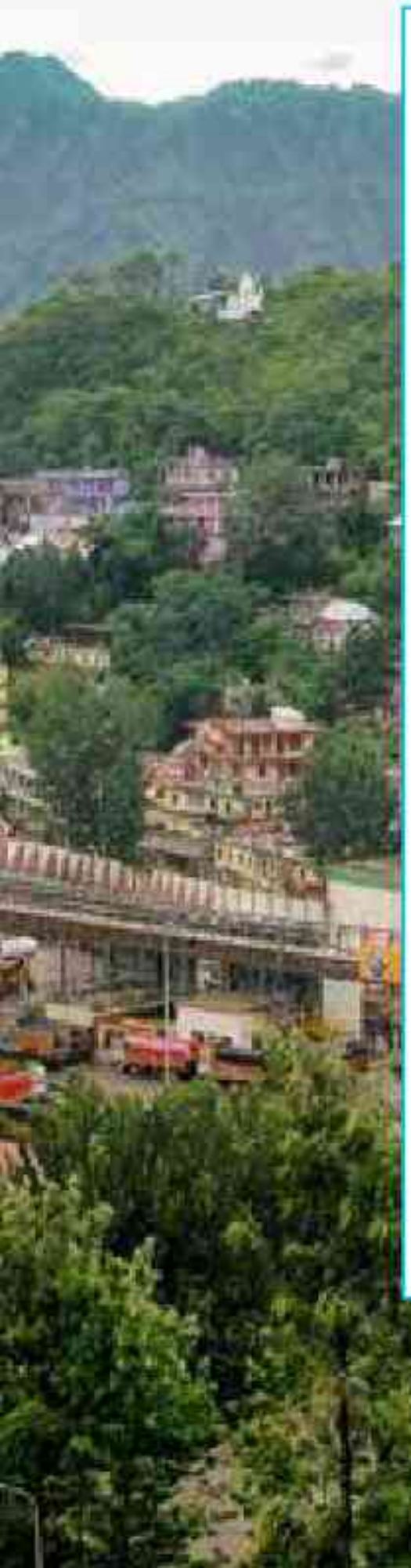
"While the global GCCA Cement and Concrete Industry Roadmap for Net Zero CO_2 is at the concrete level with a net zero target by 2050, the India-specific roadmap focuses on 2070 to align with the Government of India's Net Zero CO_2 target. It is, however, acknowledged that this Indian roadmap's decarbonizing pathway can be accelerated with active policy support from the government, enabling compliance with the 1.5-degree scenario and achieving net zero CO_2 emissions at the concrete level by 2050".

Acknowledgements

GCCA India acknowledges the support provided by The Energy and Resources Institute (TERI) for the development of this document. We are grateful for the active involvement of the Task Force members from the GCCA India member companies. We are thankful to the Cement Manufacturers' Association (CMA) for their valuable comments and feedback on the document.

GCCA India and TERI are thankful to Mr Parth Jindal (Chair, GCCA India & Managing Director-JSW Cement), Mr Thomas Guillot (CEO, GCCA) and Dr Vibha Dhawan (Director General, TERI) for providing overall vision and encouragement for the development of this document. We also thank Dr Andew Minson (GCCA) and Mr Dennis Behrouzi (ECRA) for their regular feedback and valuable inputs. The contribution by IIT-Roorkee, GCCA India member company representatives and other stakeholders who have provided inputs for the roadmap development is duly acknowledged.

We would also like to acknowledge and express our gratitude to Dr Shashank Bishnoi (Professor, IIT-Delhi), Mr Sivaram Krishnamoorthy (Deputy Director-Industry, SED Fund) and Dr L P Singh (Director General, National Council for Cement and Building Materials [NCB]) for providing valuable inputs in the development of this document. GCCA India and TERI acknowledge the financial support received from the SED Fund for the preparation of the cement sector roadmap.



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Abbreviations

AAC	Autoclaved Aerated Concrete
AFR	Alternative Fuels and Raw materials
BAU	Business-as-usual
BCSA	Belite Calcium Sulfoaluminate
BEE	Bureau of Energy Efficiency
BF – BOF	Blast Furnace – Basic Oxygen Furnace
BIS	Bureau of Indian Standards
C&D	Construction & Demolition
CCS	Carbon Capture and Storage
CCSF	Common Carbon Storage Facilities
CCTS	Carbon Credit Trading Scheme
CCUS	Carbon Capture, Utilization and Storage
CMA	Cement Manufacturers' Association
COP	Conference of Parties
CPP	Captive Power Plant
CST	Concentrated Solar Thermal
DC	Designated Consumer
DPIIT	Department for Promotion of Industry and Internal Trade
EBA	Ecosystem-based Approach/ Ecosystem-based Adaptation
ECRA	European Cement Research Academy
FGD	Flue Gas Desulfurization
GCCA	Global Cement and Concrete Association
GDP	Gross Domestic Product
GGBS	Ground Granulated Blast-furnace Slag
Gt	Giga tonne
GOI	Government of India
GHG	Greenhouse Gas emissions
HPGR	High Pressure Grinding Rolls
ICM	Indian Carbon Market
IDDI	International Deep Decarbonization Initiative
IEA	International Energy Agency
IFSCA	International Finance Service Centre Authority
IPCC	Intergovernmental Panel on Climate Change
LC3	Limestone Calcined Clay Cement
MIT	Massachusetts Institute of Technology

MoEFCC	Ministry of Environment, Forest and Climate Change
MPP	Mission Possible Platform
MSW	Municipal Solid Waste
Mt	Million tonne
MVA	Monitoring, Verification & Accounting
NbS	Nature-based Solutions
NBT	National Biodiversity Targets
NCB	National Council for Cement and Building Materials
NDC	Nationally Determined Contribution
NITI Aayog	National Institution for Transforming India Aayog
NIP	National Infrastructure Pipeline
NLP	National Logistics Policy
NSP	National Steel Policy
NMP	National Master Plan
OPC	Ordinary Portland Cement
PAT	Perform, Achieve and Trade
PLC	Portland Limestone Cement
PPC	Portland Pozzolana Cement
PPP	Public-Private Partnership
PSC	Portland Slag Cement
RBPC	Reactive Belite rich Portland Cement
RDF	Refuse-Derived Fuel
R&D	Research and Development
RE	Renewable Energy
RMC	Ready-Mix Concrete
SCM	Supplementary Cementitious Material
SDG	Sustainable Development Goal
SEC	Specific Energy Consumption
TERI	The Energy and Resources Institute
toe	Tonnes of Oil equivalent
TRL	Technology Readiness Level
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
VFD	Variable Frequency Drives
VRM	Vertical Roller Mill
WHR	Waste Heat Recovery

Executive Summary

The cement industry is one of the core industries in India and holds significant importance in the country's economy. India is the second largest cement producer in the world, accounting for 8% of total installed capacity. The per capita consumption of cement in India is 257 kg, far less than the global average of 540 kg (DPIIT, 2023). The sector generates about 20,000 downstream jobs for every million tonne of cement produced (CMA, 2022).

The cement sector's growth is primarily attributed to the country's rapid urbanization and increasing demand for housing and infrastructure requirements. It is essential to strike a balance between meeting the increasing demand and incorporating sustainability and environmental concerns. Over the years, the cement industry has evolved to become one of the trendsetters in the country in terms of energy efficiency, quality control, and environmental sustainability (MoEFCC, 2022); it has achieved one of the lowest emission intensities in the world.

The Indian Cement Roadmap: Net-Zero CO_2 by 2070

The Indian cement industry Net-zero CO_2 roadmap 2070 has been developed by Global Cement and Concrete Association (GCCA), India in collaboration with The Energy and Resources Institute (TERI) with an objective to chart out the pathway for a net-zero cement sector by 2070. The cement industry aims to align its strategies with India's Net-Zero 2070 target and Nationally Determined Contributions (NDCs), supported by an enabling policy framework.

The development of this roadmap was done with the active involvement of key stakeholders including cement industry, architects, engineers, R&D institutions, academia, and sectoral experts. The roadmap development process used the tool prepared by the European Cement Research Academy (ECRA) for developing "The Global Cement and Concrete Industry Roadmap for Net-Zero Concrete" as the basis for the quantification of various decarbonization levers.

Decarbonization Levers

It is envisaged that the cement production in India would increase from 334 million tonnes in 2019–20 to 1546 million tonnes in 2070 with a CAGR of 3.1% over a 50-year timeframe. This would lead to an increase in per capita cement consumption to around 877 kg. The key decarbonization levers identified to achieve net-zero CO_2 in cement industry by 2070 include: (1) Clinker efficiency (specific thermal energy consumption), (2) Alternative fuels, (3) Enhanced use of Supplementary Cementitious Materials (SCMs), (4) Decarbonization of electricity, (5) New binders, (6) Carbon Capture, Utilization and Storage (CCUS), (7) Recarbonation and (8) Cement-use efficiency.

The overall emission intensity[1] of the cement sector would reduce from 0.68 tonne CO_2 per tonne cement (2020) to 0.56 tonne CO_2 per tonne cement (2030) and to 0.51 tonne CO_2 per tonne cement (2047) while envisaging net zero CO_2 by 2070. Net-zero emissions in the cement sector can be achieved only through CCUS while also considering recarbonation (carbon uptake).

[1] Includes scope-1 and scope-2 emissions; excludes emissions from CPPs

1. **Clinker efficiency:** The average clinker efficiency, i.e., specific (thermal) energy consumption (SEC) level of Indian cement plants is envisaged to reduce from 731 kcal per kg clinker in 2020 to 705 kcal per kg clinker in 2070. It is envisaged that the cement industry would increase the share of biomass as fuel. Further, the low carbon fuel-mix would have a substantial share of green hydrogen along with innovative technologies such as kiln electrification, solar thermal, etc., which would perhaps become viable beyond 2047.

2. **Alternative fuels:** The Indian cement industry is envisaged to use about 35% of fossil fuel wastes as alternative fuels, which would help in shifting towards 100% low-carbon fuel-mix by 2070.

3. **SCMs:** Blended cements will continue to dominate the Indian cement industry as compared to Ordinary Portland Cement (OPC). Apart from blended cements such as Portland Pozzolana Cement (PPC) and Portland Slag Cement (PSC), it is envisaged that composite cement, Limestone Calcined Clay Cement (LC3), and Portland Limestone Cement (PLC) would play a major role in total cement production in 2070. The overall clinker factor will reduce from 0.75 in 2020 to about 0.56 in 2070.

4. **Decarbonization of electricity:** The industry would adopt three-pronged approach comprising: (i) efficiency improvements in electricity use, (ii) maximizing WHR potential and (iii) shift to green electricity with renewable energy use (either through onsite generation, open access or 'group captive plants') for complete decarbonization of electricity. Some of the cement plants have already started moving in this direction with clear plans for 100% renewable energy usage.

5. **New binders:** With the ongoing initiatives for the development and utilization of increasingly more clinker-efficient cements, there exists potential for innovative binders such as geopolymers, carbosilicate and calcium hydro silicate binders. The share of new binders is small due to the limited availability of required raw materials. However, extensive research is required before their actual potential can be gauged.

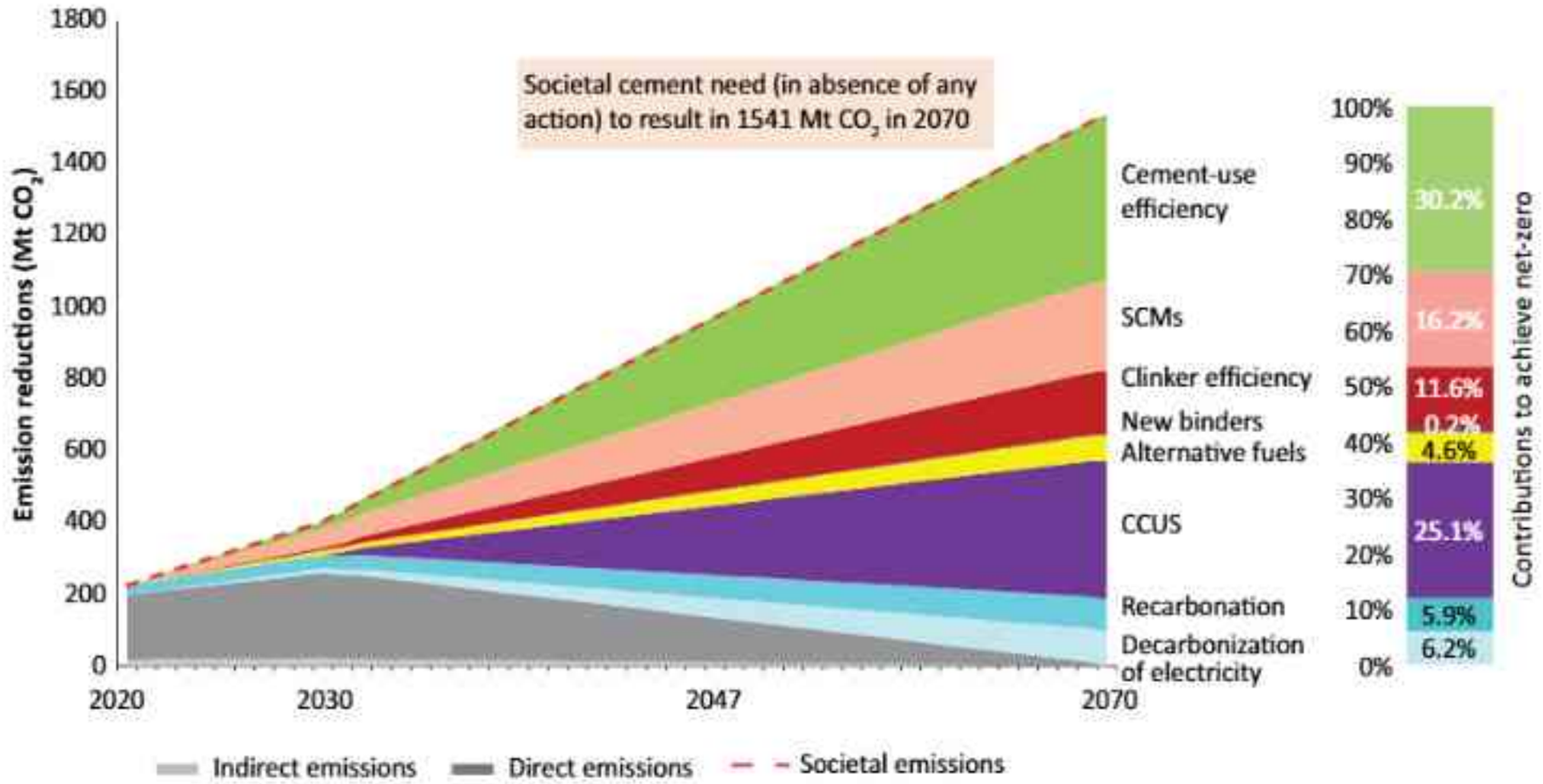
6. **Carbon Capture, Utilization and Storage:** With process emissions accounting for a significant share of emissions, cement industry needs to adopt Carbon Capture, Utilization, and Storage (CCUS) to reach to the net-zero stage. As per the modelling results, CCUS would account for about 25% of total emission reductions in 2070. It is further envisaged that 'Nature-based Solutions' (NbS), e.g., agro-forestry could play a complementary role in combating carbon emissions. A collaborative approach between industry, government and other key stakeholders would strengthen the efforts.

7. **Role of recarbonation:** Recarbonation is a natural process of CO_2 uptake by concrete which reduces whole life GHG emissions. Since India-specific recarbonation values are not available at present, the roadmap uses global values and further recommends specific studies for development of India-specific numbers.

8. **Cement use efficiency:** Discussions with various stakeholders revealed that ample opportunities exist for improving the cement use efficiency in all the end use segments. It is envisaged that the improvements in cement use efficiency would help in reducing societal demands for cement by about 30% in 2070. This includes aspects around efficiency in concrete production and efficiency in design & construction. The role of ready-mix concrete, increased use of pre-cast structures, design optimization technologies, construction site efficiency, increased lifetime of buildings, optimized mix designs, etc., are all covered under this lever.

Net-Zero CO_2 2070 Pathway for the Cement Sector

The 2070 net-zero CO_2 pathway for the Indian cement industry shows that cement-use efficiency and CCUS would be the dominant decarbonization levers in achieving net-zero by 2070, contributing to about 30% and 25% respectively of total CO_2 emissions.



Net-zero CO_2 2070 pathway for Indian cement sector

Enabling Policy Framework

The key 'policy asks' by the Indian cement industry that would support its net-zero CO_2 2070 journey are as follows:

Establish supply chain for alternative fuels: The cement industry would need a robust supply chain network for alternative fuels like RDF obtained from municipal solid wastes, used tyres, plastic wastes, etc. This would help in efficient utilization and better societal waste management. Suitable policies towards land availability for 'captive biomass generation' to use biomass as a partial/ full replacement of fossil fuels for thermal energy requirements would be extremely important.

Promote low carbon cement: Increased use of greener varieties of cement would require (i) introducing definition for low carbon cement, (ii) strengthening public procurement policy/demand for low carbon cement in government funded infrastructure and housing projects, and (iii) making suitable amendments and introduce new standards for blended cement. The government should also initiate detailed geological mapping for clay reserves which can be used as a complementary SCM in blended cement production especially for LC3 production.

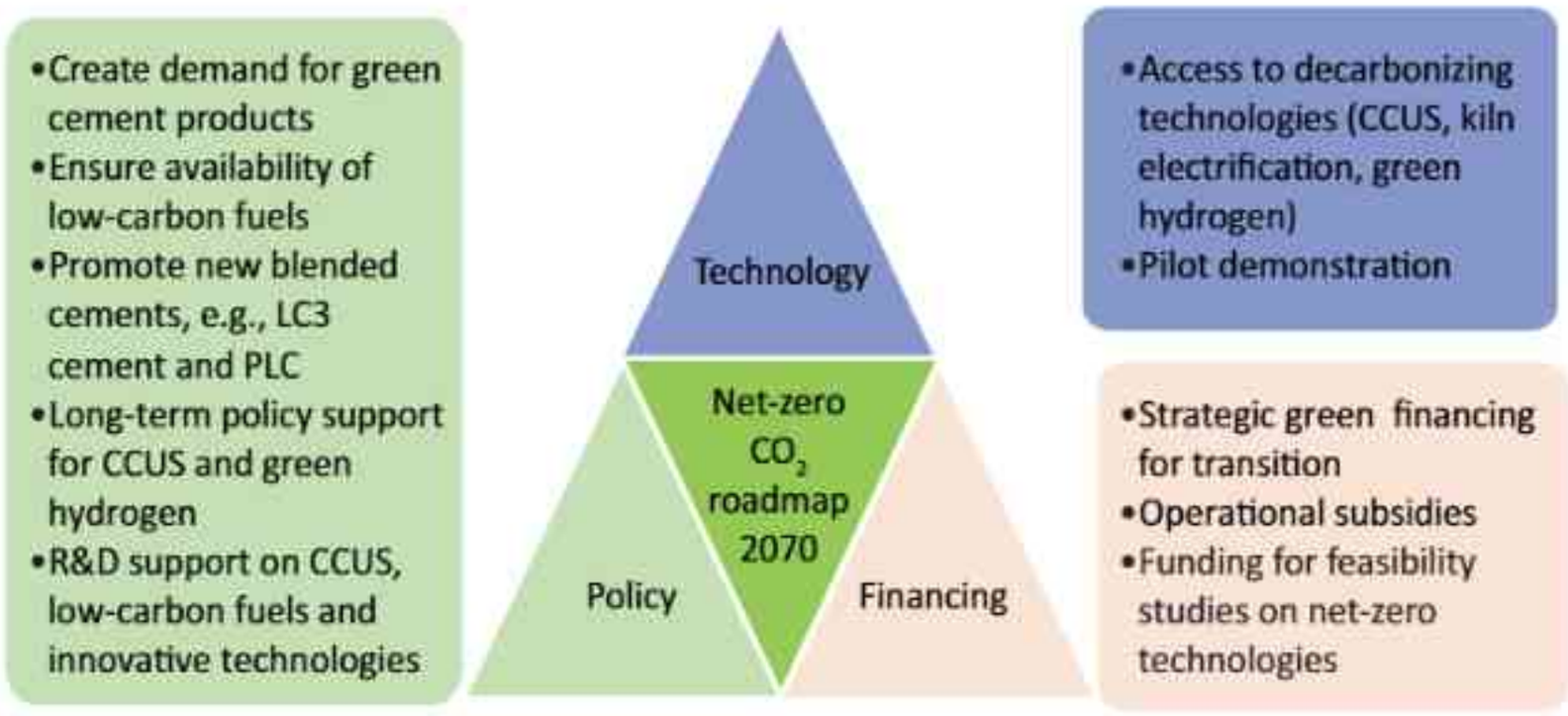
Cement use efficiency: Cement use efficiency is an important decarbonization lever in the value chain that includes efficient concrete production and optimizing design and construction. The shift to industrial concrete production will help in efficient cement utilization. Increased weightage for embodied CO_2 emissions reduction in green building certifications will aid efficient cement utilization in concrete.

Long-term policy support for CCUS: The cement industries would require financial and policy support for conducting 'detailed studies' on CCUS projects at the plant level as well as for actual implementation of CCUS projects. It may be noted that CCUS projects require additional capex which is very high and cannot be absorbed by the cement plants. Globally, CCUS projects are

funded through government supported programmes. Long-term legal certainty for CO_2 storage and transportation facilities will also be a pre-requisite. The government will need to develop essential infrastructure for CO_2 transport & storage facilities while ensuring public acceptance. Geological CO_2 storage & transport may require substantial land areas. The industry would also require tools for 'Monitoring, Verification and Accounting' for CO_2 storage system. Nature-based Solutions (NbS) can be a complementary lever to support decarbonization efforts.

Establish strategic green financing: A 'strategic green financing' programme dedicated for the cement sector would be required to support the transition process in the Indian cement industry. It should support innovation, R&D and pilots for a few initial projects in areas like green hydrogen, kiln electrification, CCUS, newer cement production technologies, etc. Subsequently, as the industry progresses in adopting deep decarbonization technologies, operational subsidies and low cost financing from international sources would be needed to ensure a transition to net-zero CO_2 cement sector.

The cement industry is ready to embark on an exciting net-zero pathway. However, this requires collaborative efforts and joint action by policymakers, relevant ministries, investors, researchers, innovators, customers, end users, and financial institutions.



Key enablers for net-zero CO_2 cement sector roadmap

Decarbonizing the cement and concrete industry requires a comprehensive, multi-phase approach to policy support that addresses the varied challenges at different stages of the transition. In the near term, the industry needs policies that focus on incentivizing immediate emission reductions through the adoption of available low-carbon technologies, such as energy-efficient production processes and the use of alternative fuels.

In the medium to long term, policies should promote the scaling up of emerging technologies like Carbon Capture and Storage (CCS), green hydrogen use, and alternative binders, while also supporting research into new materials and methods. This could involve public-private partnerships (PPPs), long-term funding for R&D, and carbon pricing mechanisms that reflect the true cost of low carbon production.

The industry will need a multi-pronged focus on technology adoption, innovation acceleration and research deployment for deep decarbonization. Additionally, a harmonized global approach to standards and emissions reductions will be essential to ensure competitiveness, mitigate trade risks, and drive further innovation across the sector. The policy landscape must evolve at each stage, with different tools and incentives tailored to the progress and readiness of the technology and market to deliver on decarbonization goals.

Background

The Indian cement industry is a global leader in adopting sustainable practices and has achieved one of the lowest values of emission intensity in the world (MoEFCC, 2022). The cement industry has been a part of various 'Perform, Achieve and Trade' (PAT) cycles of the Government of India and many of the cement plants have been able to overachieve their energy intensity reduction targets. India's long-term low carbon development strategy reiterates enhanced use of alternative fuels and raw materials (AFR) and 'Refuse-Derived Fuel' (RDF) in the cement industry (MoEFCC, 2022). This would help in contributing to increased circularity in the Indian economy as well as accelerate the low carbon trajectory of the sector.

The Government of India has given continuous impetus to the manufacturing sector, which not only contributes to the country's GDP but also towards generating employment, creating infrastructure and improving the well-being of its citizens. With raising demands in infrastructure, the demand for cement is likely to increase many folds in the medium and long-term.

A roadmap of the global cement and concrete sector was launched by the Global Cement and Concrete Association (GCCA) just before the Conference of the Parties (COP26) hosted by the UNFCCC in Glasgow in 2021. The global roadmap elucidated a net-zero pathway to help limit global warming to 1.5°C. It is a collective commitment of the world's leading cement and concrete companies, developed with inputs from nine regions including India. It was developed with detailed inputs from all global regions of GCCA with many of the members as well as other sector players contributing to the process (GCCA, 2021).

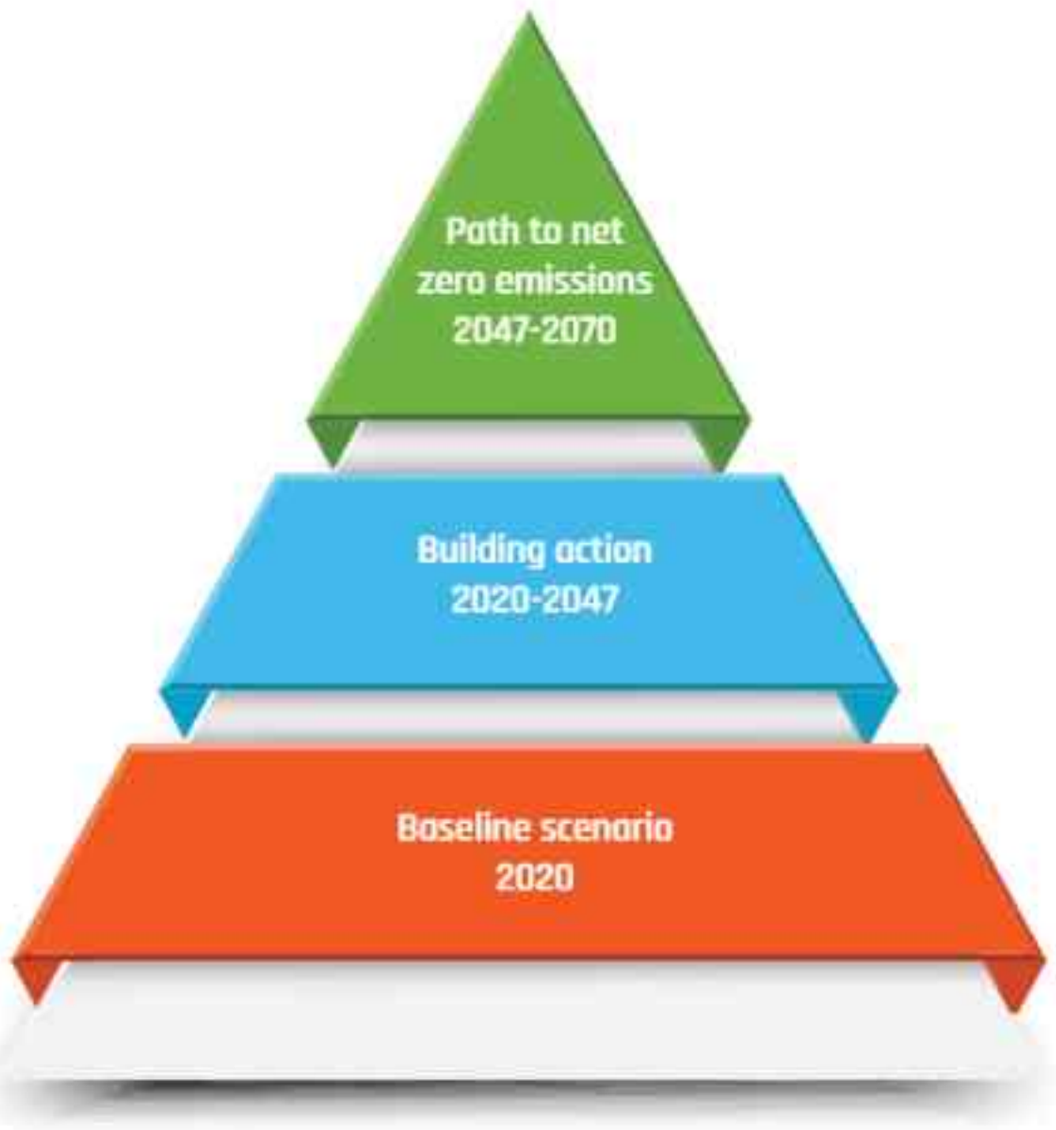
Members of GCCA India, affiliated with GCCA, aspire to achieve net-zero emissions. The members would contribute to the decarbonization efforts in line with their position in the cement sector production value chain. As a part of the Global Net Zero accelerator initiative, an India-specific roadmap for the cement industry has been developed aligning with the Government of India's Net-Zero 2070 target. This document is based on a global framework to provide India-specific technology decarbonization levers and the need for an enabling policy ecosystem.

The India-specific 2070 roadmap is an initiative and an aspiration of the Indian cement industry to continue and accelerate its efforts on decarbonization, set goals in line with India's updated Nationally Determined Contributions (NDCs) and align its strategies with the Government of India's targets supported by an enabling policy framework. The GCCA India, in this regard, thus becomes a crucial platform for becoming the voice of the industry, and supporting action for the industry to achieve net-zero CO_2 emissions. The Energy and Resources Institute (TERI) has collaborated with GCCA India to develop an India-specific net-zero CO_2 roadmap for the Indian cement sector with inputs from all relevant stakeholders. The roadmap considers the mid-term goal for 2047 (Viksit Bharat) and achieving net-zero emissions by 2070.

Purpose and Scope

Cement production is highly emission intensive and is globally considered as one of the 'hard-to-abate' sectors. There are technological solutions that could be implemented to achieve 'close to zero' emissions by the cement industry. However, decarbonizing the cement sector is more than a technological transition. Some of the radical decarbonization technologies such as 'Carbon Capture, Utilization, and Storage' (CCUS), electrification of kilns, and use of new innovative production techniques which are currently at the lab/pilot stage or being demonstrated would become commercially available only in the long term. CCUS, in particular, will be crucial for achieving net-zero emissions in the cement sector. Therefore, addressing the emissions challenge would require a broader systemic transformation. The cement industry is deeply embedded in our economies and societies; its decarbonization can be viewed as a major socio-technical transition involving co-evolutionary shifts in markets, business models, policies, infrastructure, demand-side behaviour norms and institutions (LeadIT, 2022).

With net-zero targets emerging at the country level, professionals worldwide are advocating that local centricity must be right at the centre-stage of the development of any roadmap. Every industry, region, and country has specific and distinct opportunities and challenges, implying that the approach to a specific roadmap to Net Zero CO_2 cement may vary as the technology levers may be applied in different ways, most relevant to the region and specific to local conditions. Achieving net-zero emissions in the cement sector, therefore requires an understanding of local context and opportunities. Roadmap to decarbonization can provide a framework to set targets, timelines, and align policy instruments, investments, and promote innovation. By tailoring strategies to region or country specific, the risks of being locked into higher emission trajectories due to the long lifespan of industrial assets can be minimized to a large extent.



Path to Net Zero CO_2 cement (2020-2070)

The Indian industry is considering the next 25 years till 2047, India's 100 years since it became an independent nation, as a "Period of Action", aligning with the Government of India's target of Viksit Bharat.

India is the second largest cement producing country in the world. With net-zero commitments from many Indian cement companies as the sound backdrop of a low carbon strategy, the India-specific roadmap is based on its global counterpart; it includes decarbonization levers to develop indigenous scenarios whilst drawing inputs from relevant stakeholders from the cement sector.

The roadmap considers the following:

- 2019–20 is considered as the baseline year for cement production
- An outlook and milestones for transitions of the industry by 2047
- Achieving Net Zero CO_2 cement by 2070

The societal demand for cement is projected to increase substantially with increasing demand from the housing and infrastructure sectors. In a business-as-usual scenario, the total societal demand for cement would reach about 2278 million tonnes in 2070. However, with various efforts being undertaken in end-use sectors such as concrete production, design and construction, it is envisaged that cement-use efficiency would reduce cement demand by about 30.2% in 2070 to about 1546 million tonnes. This translates to around 877 kg per capita consumption in 2070 from a current level of 257 kg.

This India-specific roadmap comprises numerical modelling and forecasting as well as the need for an enabling policy and financial environment. The numerical modelling of the Indian cement sector uses the tool developed by the European Cement Research Academy (ECRA) along with GCCA. However, it is considering the decarbonization levers relevant only to the cement sector while the model allows the inclusion of natural recarbonation of concrete (GCCA, 2021). It, therefore, enables consistent definitions, calculation procedures and presentation for comparison with other countries, regional and global roadmaps that use the ECRA methodology.

Various experts representing cement industries, construction companies, research institutions, regulatory and industrial bodies in India have played an important role in developing the India-specific cement industry roadmap 2070. This roadmap includes only Scope-1 and Scope-2 emissions; excludes emissions from captive power plants. An integrated blueprint in pursuit of net-zero emissions set out by the existing global framework forms the overall basis of the cement sector roadmap in India.

1

Global Cement Industry

The cement and concrete industries are an integral part of the construction sector and contribute to about 13% of global Gross Domestic Product (GDP) (GCCA, 2021). According to the International Energy Agency (IEA), the cement sector is the third largest industrial energy consumer in the world and the second largest industrial emitter of CO_2. The cement industry was responsible for about 8% of global emissions in 2022 (WEF, 2024).

The demand for cement, the key ingredient of concrete, can be attributed to infrastructural development and the growth of construction sector with rapid urbanization across the world. Concrete is one of the most consumed resources globally with its usage surpassing that of all other building materials combined. The increasing adoption of concrete in the construction of eco-friendly, sustainable, and resilient buildings and infrastructure will further promote the growth of the cement industry. The global cement production stood at about 4158 million tonnes during 2022 (IEA, 2023) (Figure 1).

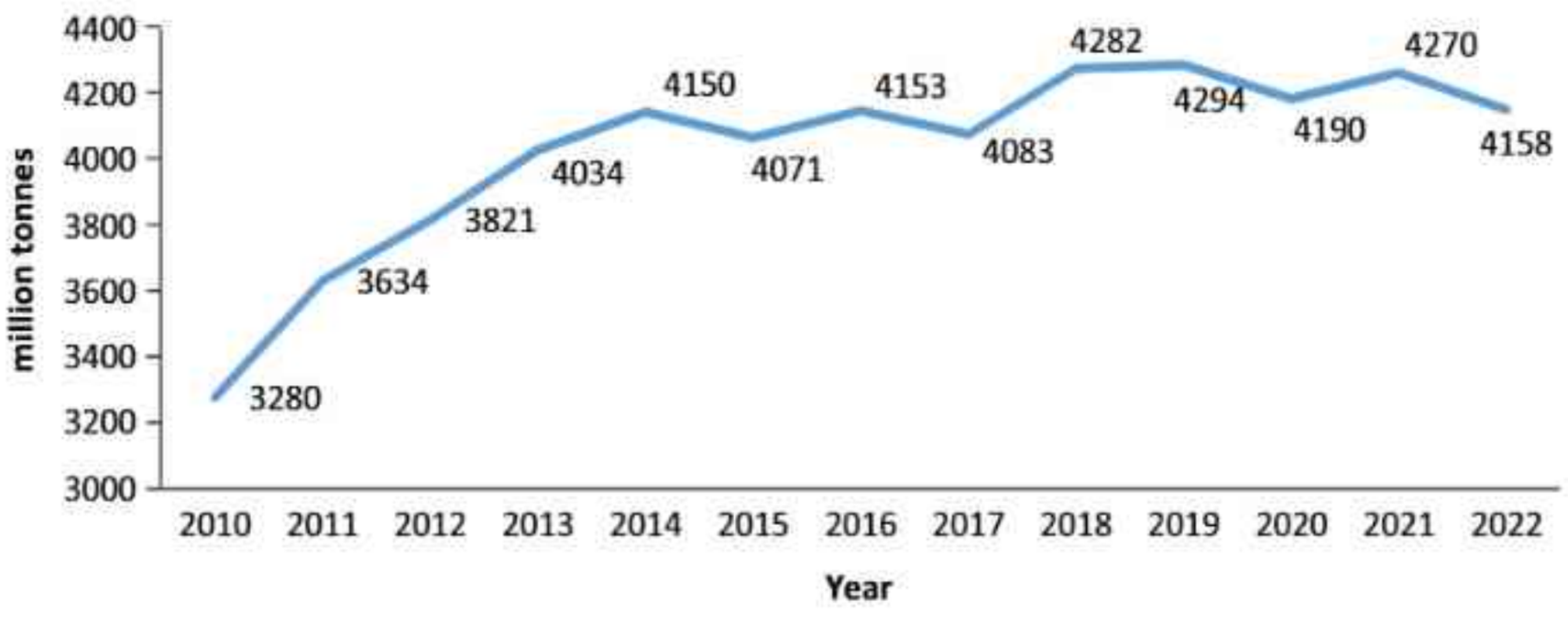


Figure 1: Global cement production trend

There has also been a steady shift in economies across the globe from producing concrete on small project sites using bagged cement to utilizing factory production of ready-mix or precast concrete. In developed economies, digitization is now being introduced. Amongst the benefits of all these advancements, is a reduction of CO_2 footprint for equivalent performing concrete.

The total global CO_2 emissions from cement sector are estimated to be in excess of 2.5 Giga tonnes (Gt) (GCCA, 2021). These are direct CO_2 emissions, which are primarily from the calcination of limestone itself which is about 60% and combustion of fossil fuels usage in cement production about the remaining 40% (GCCA, 2021). At global level, the cement industry has worked over the last two decades to improve productivity, enhance energy efficiency and reduce CO_2 emissions. Cement industry was the first sector to monitor and publicly report its CO_2 emissions (GCCA, 2021).

The global roadmap considers the value chain of cement, i.e., both cement and concrete industries for net zero CO_2 emissions by 2050 (Figure 2).

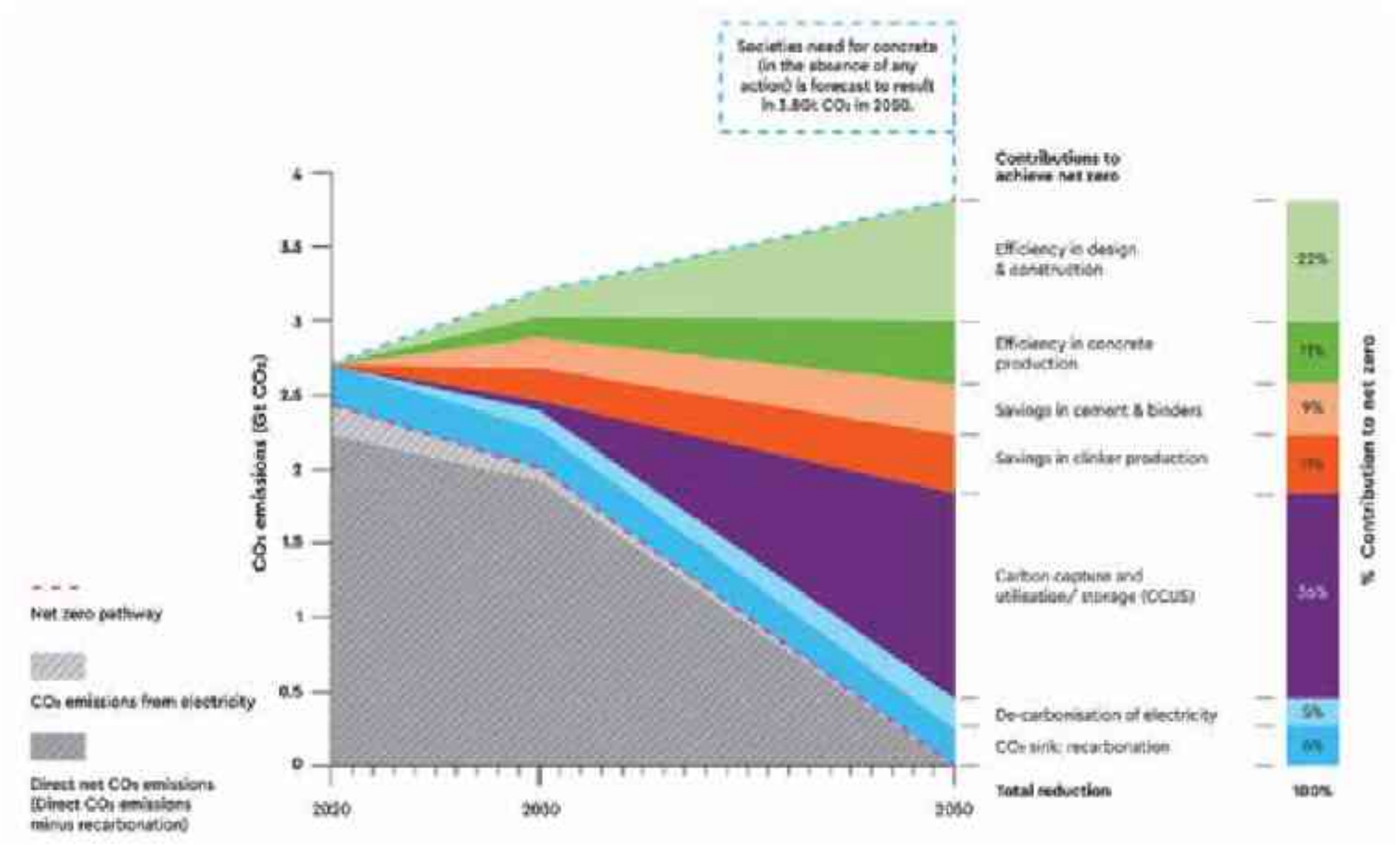


Figure 2: Net Zero CO_2 Concrete Roadmap

2

Indian Cement Industry

The cement industry is closely linked to the demand and growth trends of the construction sector. India's current development policies are designed to spur growth in construction of houses in rural areas, growth of urban infrastructure and urban commercial centres, as well as in infrastructure for improved mobility, freight connectivity, warehousing, supply of water, etc., which in turn would enhance the significance of the cement sector in the overall economy. The construction sector had a GDP contribution of INR 14.08 trillion in 2023 (~1% of the GDP) (Statista, 2023). Moreover, India's cement industry provides employment to more than a million people directly or indirectly. The cement sector generates about 20,000 downstream jobs for every million tonne of cement produced (CMA, 2022). India is the second largest cement producer accounting for 8% of global installed capacity. The per capita consumption of cement in India is 257 kg, far less than the global average of 540 kg (DPIIT, 2023).

The total installed capacity of Indian cement sector was 600 million tonnes (Mt) during 2022–23 (PIB, 2024). Of this, about 98% belongs to the private sector. The cement production during the base year, i.e., 2019–20 was 334 Mt (Figure 3). Indian cement industry comprises about 158 integrated large cement plants, 116 grinding units, 62 mini-cement plants and 5 clinkerization units (DPIIT, 2023). Over the years, the Indian cement industry has evolved to become one of the best industries in terms of energy efficiency, quality control, and environmental sustainability.

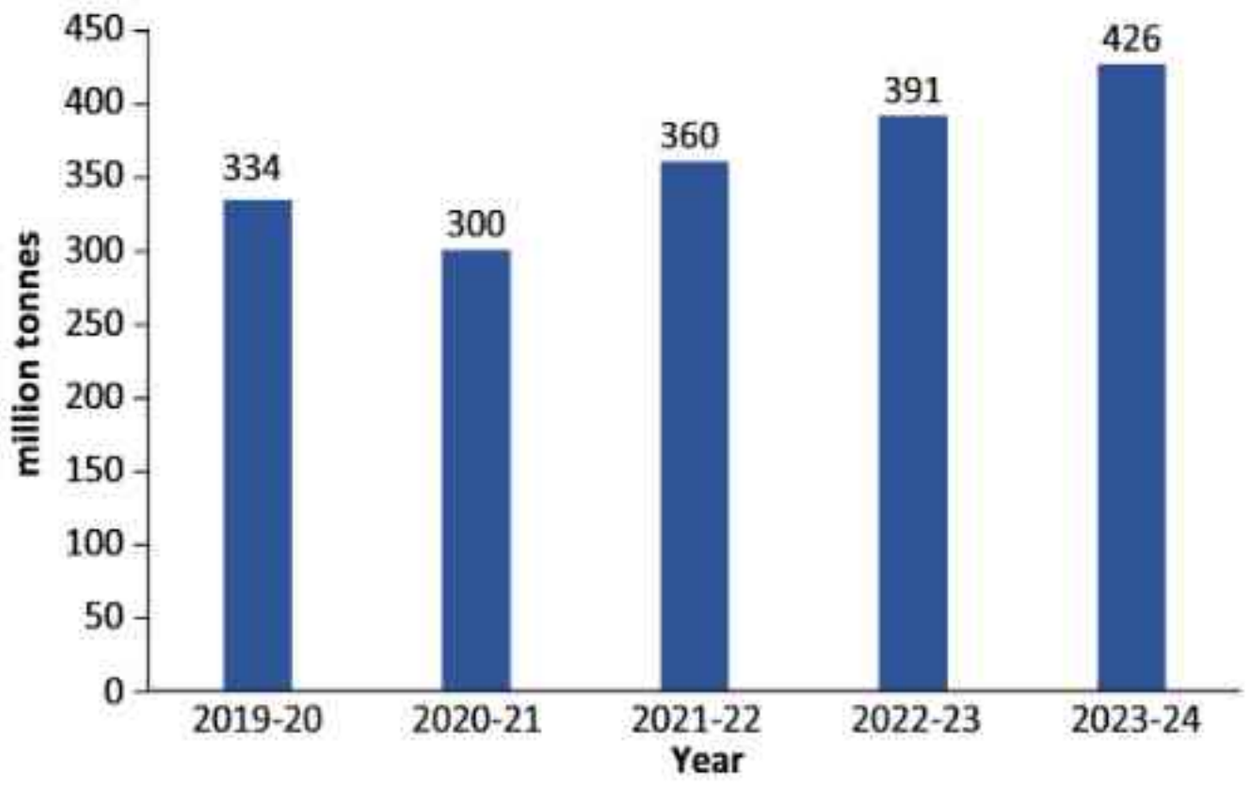


Figure 3: Cement production trend in India

India has integrated its development goals with ambitious climate action goals, be it in the form of augmented wind and solar power capacity (installed), mandatory energy saving targets in energy intensive end-use sectors, and improved green cover facilitated by Green India Mission, among other targeted government actions. The cement sector has contributed in all these areas in terms of enhanced actions.

The cement industry plays a crucial role in the development of the housing and infrastructure sectors. It contributes immensely to the implementation of government schemes like housing for all, smart cities, roads, bridges and highways, dedicated freight corridors, metro corridors, ultra mega power projects and waterways. It has been a significant contributor to employment generation, fiscal revenue, and community development. The industry has witnessed manufacturing and technological advancements, which have further enhanced its growth and productivity. There exists substantial potential for the growth of the cement industry in India, given the huge emphasis of the Government of India on infrastructure and housing sectors.

2.1 Cement manufacturing process and technology use

About 99% of total installed capacity of Indian cement plants use energy efficient dry process based kilns. With consistent efforts, cement industry has improved its overall energy performance. Over the last decade, the cement industry has further adopted automated processes and latest technologies for combustion control, clinker cooling, grinding, digitalization, etc., which have enabled the industry to perform at par with the best cement industries in the world.

2.2 Fuel-mix in cement production

Indian cement industry extensively uses petcoke and coal as major fuels for clinker production (Industry data analysis, TERI, 2022); these fuels accounted for more than 95% of thermal energy demand during 2020–21 (Figure 4). Majority of cement industries have already initiated using alternative fuels as thermal substitution in kilns and pre-calciners, the usage of which still remains at low levels. These alternative fuels include municipal solid wastes (MSWs), industrial wastes, used tyres, harvested biomass, etc. The extent and level of use of alternative fuels depend on their availability, price, and accessibility and often require pre-processing before being used in kilns as a fuel.

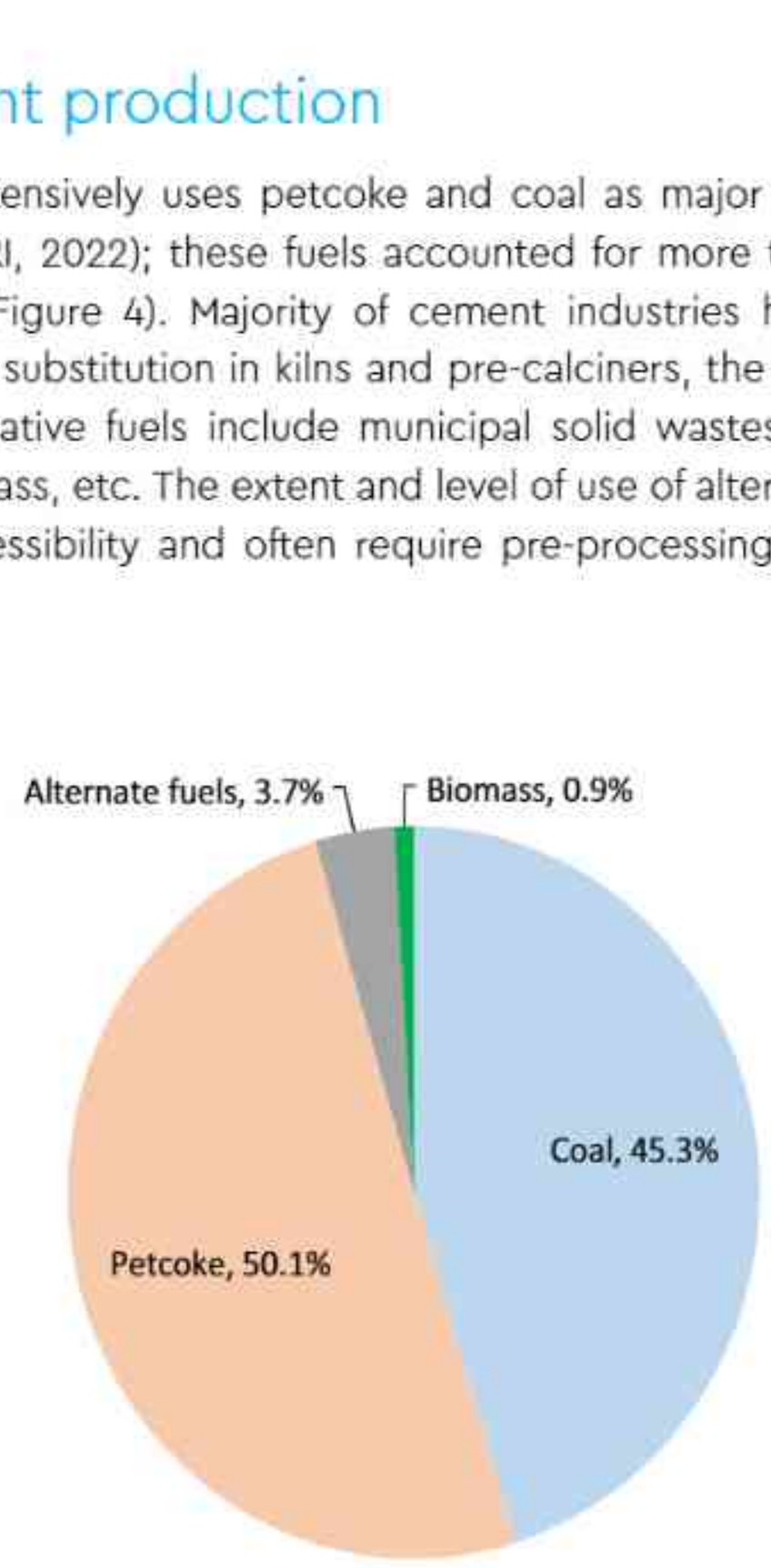


Figure 4: Fuel-mix share (thermal energy demand)

2.3 Energy consumption

Cement production process is thermal energy intensive, mainly for clinkerization in rotary kilns; thermal energy accounts for 85–90% of total energy consumption in cement production (Industry data analysis, TERI, 2022). Electrical energy constitutes the remaining 10–15% towards raw material processing and cement grinding.

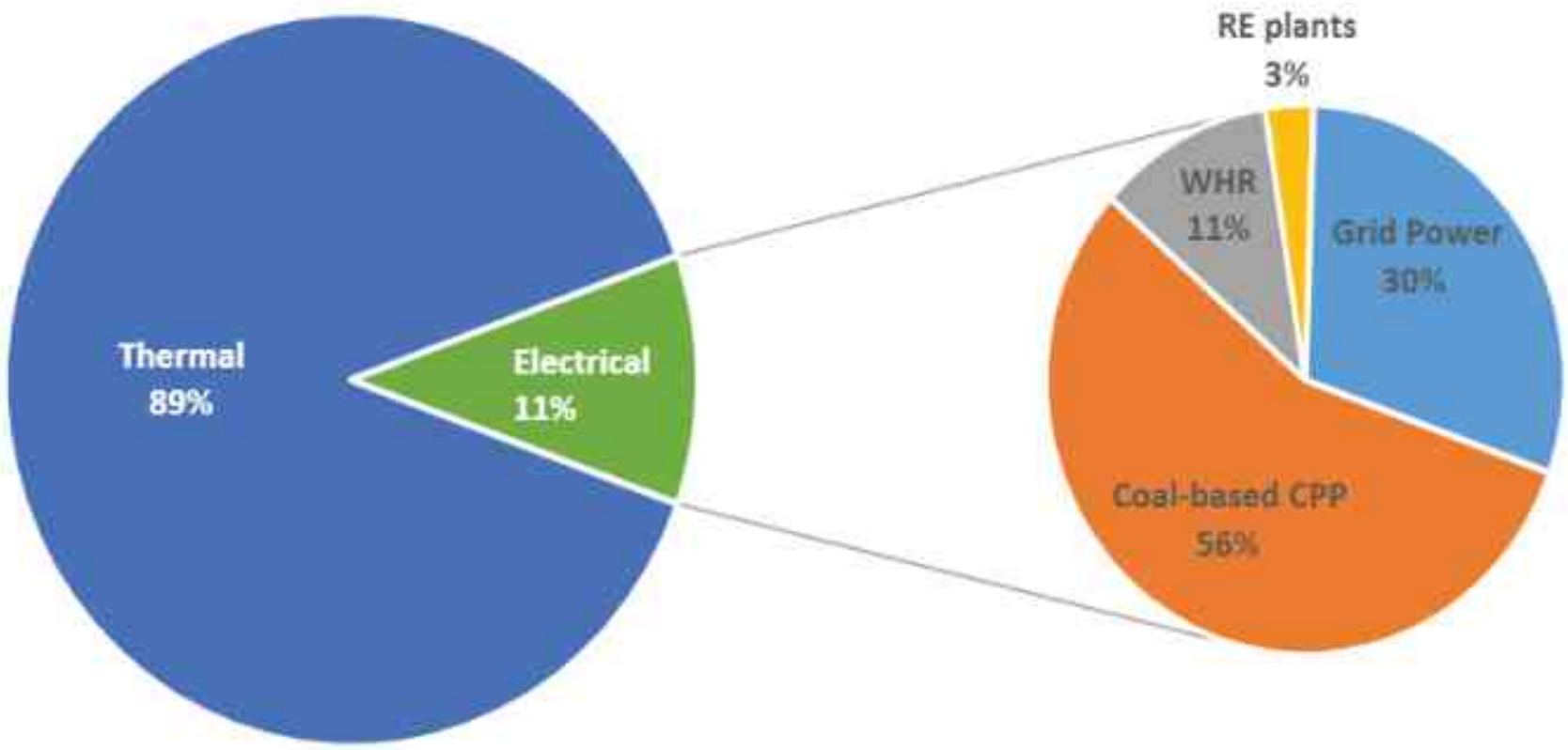


Figure 5: Energy share in cement production

A large number of cement industries in India have installed coal-based captive power plants (CPPs) and waste heat recovery (WHR)-based power generation systems. It also uses renewable-based electricity to a small extent. The share of electricity consumption in Indian cement industry shows 56% by coal-based CPPs, 11% by WHR plants, 3% by renewable energy and 30% grid (Figure 5) (Industry data analysis, TERI, 2022).

The weighted average specific energy consumption (SEC) of Indian cement industries stood at 731 kcal per kg clinker (thermal) and 73 kWh per tonne cement (electrical) during 2020–21 (Table 1).

Table 1: SEC levels of Indian cement plants

Details	Unit	Range	Weighted average
SEC-Thermal	kcal per kg clinker	695–763	731
SEC-Electrical	kWh per tonne cement	64–79	73

Source: Industry data analysis, TERI, 2022

2.4 Emissions from cement industry

The total emissions (Scope-1 and Scope-2) from the Indian cement sector in 2020–21 were estimated as 226 million tonnes CO_2 (Industry analysis, TERI, 2022). The major sources of Scope-1 and Scope-2 emissions from cement industries include the following (NITI Aayog, 2022):

(i) calcination process accounts for 57–60% of total emissions

(ii) process heating or combustion of fuels contributes to about 27–30% of total emissions

(iii) emissions from electricity use accounts for 10–13%

(iv) limestone mining also has a limited contribution of 1–2%

The Indian cement sector roadmap covers only emissions from sources (i), (ii) and (iii) as mentioned above. It does not include limestone mining and transportation of raw materials and finished products. Although many cement plants have installed fossil fuel-based captive power plants to meet part of their electricity demand, many have also now started using renewable energy-based electricity.

2.5 Blended cements and supplementary cementitious materials

The Bureau of Indian Standards (BIS) specifies 14 types of cement and clinker. Of these, the share of Ordinary Portland Cement (OPC) production, which has the highest clinker factor (i.e., clinker to cement ratio), was about 27% during 2020–21 (Industry data analysis, TERI, 2022).

During this period, the share of blended cement stood at about 73% of total cement production. India produces predominantly two types of blended cements—Portland Pozzolana Cement (PPC) and Portland Slag Cement (PSC). PPC had a share of 64% using fly ash as supplementary cementitious material (SCM). The share of PSC was about 7%, which uses ground granulated blast-furnace slag (GGBS) commonly known as steel slag as SCM. The cement industry produced about 2% of composite cement (Figure 6).

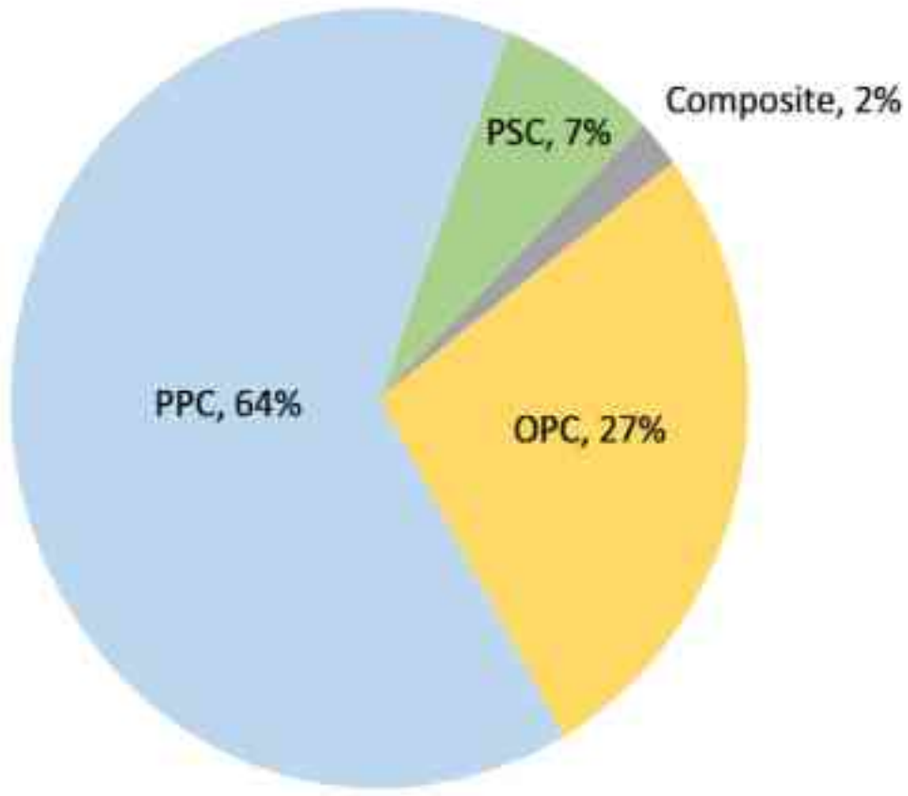


Figure 6: Share of cement types

The higher level of blended cement production may be attributed to the availability of fly ash from coal-based thermal power plants and slag from integrated steel plants using BF-BOF route along with advanced technologies in cement manufacturing. At present, commercially available PPC uses about 20–32% fly ash (against the maximum permissible limit of 35%); PSC uses upto 58% of slag (against the maximum permissible limit of 65%) (Industry data analysis, TERI, 2022).

Increased use of blended cements helps in reducing thermal energy consumption, resource use and overall CO_2 footprint in cement production due to lower clinker factor. The steady increase in blended cements share witnessed a corresponding reduction in OPC production in India. This shift is likely driven by the growing popularity of blended cements and the associated benefits in terms of sustainability and performance. Blended cements are expected to continue dominating the market and could further help in reducing clinker factor in cement production. Both types of blended cements used in India (PPC and PSC) are ideally suitable for mass concrete works, constructions in aggressive conditions such as marine, coastal, and sub-coastal environments and chemically aggressive conditions. Even under normal conditions, they impart long-term strength and better durability. All types of cements produced in India have to mandatorily confirm to their respective BIS standards.[1]

1 Fly ash conforming to standard IS: 3812(1)2013 can be used (up to 35% maximum) in the manufacture of PPC as per IS: 1489(part 1)2015. The enhanced use of fly ash in Portland Pozzolana Cement (PPC) results in the reduction of clinker factor in cement, resulting in lower CO_2 emissions. The use of PPC is permitted by the Ministry of Railways, Railway Board and Government of India projects, in substructure of bridges conforming to requirements of IS: 1489. As per the 'guidelines of high-performance concrete bridges' issued by the Ministry of Railways conforming to grade-I of IS: 3812:2003 can be used where proportion should not be less than 20% and nor should exceed 35% by mass of cement.

In the year 2015, standard: 16415–2015 was introduced for composite cement. The Indian standards and codes of practices recommend usage of composite cement only in plain cement concrete and not in reinforced cement concrete due to lack of experimental data on application and durability performance of composite cement.

Other than existing types, new blended cements like Limestone Calcined Clay Cement (LC3 cement) are presently being explored in the Indian market. This shows keen interest and efforts being made by the Indian cement industry to explore and adopt more environment-friendly alternative cement types in India. Overall, the increasing popularity of blended cements reflects the industry's commitment to sustainable practices while aligning with global efforts to address environmental challenges in the construction sector.

2.6 Ready-mix concrete and precast industries

Ready-Mix Concrete (RMC) and precast industries are end-users of cement in construction sector. However, these industries are relatively at a nascent stage in India. RMC, a corollary to bulk handling and transportation of cement offers several advantages. It is produced under controlled conditions and hence has consistency in quality, and it can be directly poured in the required form which would not only save time but also would improve the quality of construction, etc. As compared to the general use of site-based mechanical mixed concrete from the cement bag, use of RMC would yield efficiency gains in cement use and can reduce cement intensity per cubic metre of concrete.

Precast systems are increasingly being used in India for infrastructure projects, including bridges and flyovers. It proves highly efficient in terms of saving time, reducing labour requirements, improving building quality, minimizing material waste and providing flexibility for meeting various design specifications, including facades and repetitive module blocks. While establishing a precast facility would involve substantial initial investments, its rapid construction capabilities can contribute to minimizing delays in large-scale construction projects while ensuring durability of structures.

3

Major Growth Drivers

The Indian cement industry is poised for significant growth in the coming years. As per the National Commission on Population in India, about 38.6% of the population, i.e., close to 600 million people in India are expected to live in urban centres by about 2036. It is important to build 600 to 800 million square metres of urban space every year until 2030 to cater to the envisaged urban population growth in India (ANI, 2020). According to the International Energy Agency (IEA), most of the buildings that will exist in India in 2040 are yet to be constructed (IEA, 2021). This indicates the immense scope for future construction activities in the country in a sustainable way.

The growth in cement production in India is primarily attributed to the country's rapid urbanization and increasing demands for housing and infrastructure projects. Some of the major drivers of the growth of the Indian cement sector include initiatives of the Government of India, e.g., PM Gati Shakti National Master Plan (NMP) for multi-modal connectivity, affordable housing schemes, smart cities, etc., which would further fuel the demand for cement in the country.

The Government of India (GoI) has implemented several initiatives to encourage private sector participation in infrastructure development and enhance the efficiency and cost competitiveness of the sector. These initiatives include Public-Private Partnership (PPP), National Monetisation Pipeline, Gati Shakti, and the National Logistics Policy (NLP). The National Infrastructure Pipeline (NIP), 2019 of the GoI aims to develop a comprehensive plan for infrastructure development in the country. The fast-paced construction of roads, bridges, metro rail projects, national highways, expressways that has been observed during the past few years is expected to continue thereby, further increasing the demand for cement.

India announced its low emission development strategy to the UNFCCC at COP27 held in Egypt in 2022. It includes climate-resilient urban development driven by smart city initiatives, integrated planning of cities for mainstreaming adaptation and enhancing energy and resource efficiency and effective green building codes. It is essential for India to strike a balance between meeting the increasing demand for cement in construction and infrastructure developments while prioritizing sustainability and environmental concerns at national level. Implementing policies and practices that encourage energy efficiency and renewable energy use, enhancing circularity, promoting sustainable building materials, and supporting green construction initiatives are vital for managing the environmental impact of Indian cement sector.

It is envisaged that the various growth drivers would lead to enhancing the cement production by about 4–5 times in 2070 from the baseline production of 334 Mt in 2020.

4

The Action Period: 2020–2047

The cement industry believes that the period upto the year 2047 is crucial to set things in perspective for a net-zero path. The focus will be on augmenting core competencies and sustainable development of infrastructure. The Indian cement sector is required to initiate actions during this period to achieve net-zero by 2070 (Figure 7). This period, therefore, must be used to set enabling conditions towards accelerating CO_2 emission reduction in the cement sector.

Figure 7: Building action: 2020–2047

During this period, the cement industry intends to increase the use and share of various low-carbon fuels such as biomass and waste derived fuels, that would substantially decrease the fossil fuel share. It would increase the share of waste heat recovery (WHR)-based electricity from the process thereby reducing dependency on grid and/or captive power. With this ongoing energy transition journey, it is expected that Indian cement industry will be able to increase the share of renewable energy through on-site generation, group-captive or open-access routes. As the power sector decarbonizes, the grid is expected to become greener, thereby further reducing the scope-2 emissions from Indian cement plants. The cement industry will continue efforts on improving energy efficiency on thermal and electrical fronts to help in optimizing its energy demands.

The industry would like to maximize the use of existing SCMs (i.e., fly ash and slag) in blended cement production, while ensuring quality, strength, durability and other requisite parameters. It would also put in efforts to increase production of blended cements like Limestone Calcined Clay Cement (LC3) and composite cement. It would also like to introduce other SCMs (silica fumes, metakaolin, rice husk ash, etc.) as well as other cement types such as Portland Limestone Cement (PLC).

Although, the current belief is that fly ash and slag would continue to be available for the next few decades, the cement industry might witness a decreasing trend in the availability in certain geographical regions, due to decarbonization efforts envisaged in power and steel sector. The

period upto 2047 will therefore be used to ensure availability of a wide range of other SCMs in the Indian market. The cement industry would require support towards the establishment of availability and accessibility of other such SCMs.

The industry aspires to adopt new technologies and breakthrough innovations to reduce overall energy consumption and achieve net-zero emissions at national level. One of the focus areas that the industry will explore is kiln electrification; this would require concerted R&D efforts, support from policymakers and collaboration with national and international stakeholders that are also looking at such options.

Carbon Capture, Utilization and Storage (CCUS) is necessary to achieve net zero by the cement industry. The cement industry is ready to embrace CCUS on a pilot basis. A few major cement industry players in India have already initiated proactive actions in this direction. There is a need for feasibility studies and pilot demonstration plants to showcase techno-economic viability of CCUS technologies with robust government support including funding to develop appropriate technology basket options for Indian cement industry. It needs to work closely with stakeholders such as policymakers and the investment community to help develop, de-risk and deploy CCUS technologies and requisite infrastructure towards net-zero transition.

The cement industry is looking forward to an enabling policy framework during this period that would lead to the establishment of a few pilots on CCUS, kiln electrification and new SCMs that can be used for manufacture of blended cements. An active long-term association and participation of the industry, technology providers, R&D centres, financial institutions, and other key stakeholders will be required for this purpose. The key actions required in cement sector during this period is shown in Figure 8.

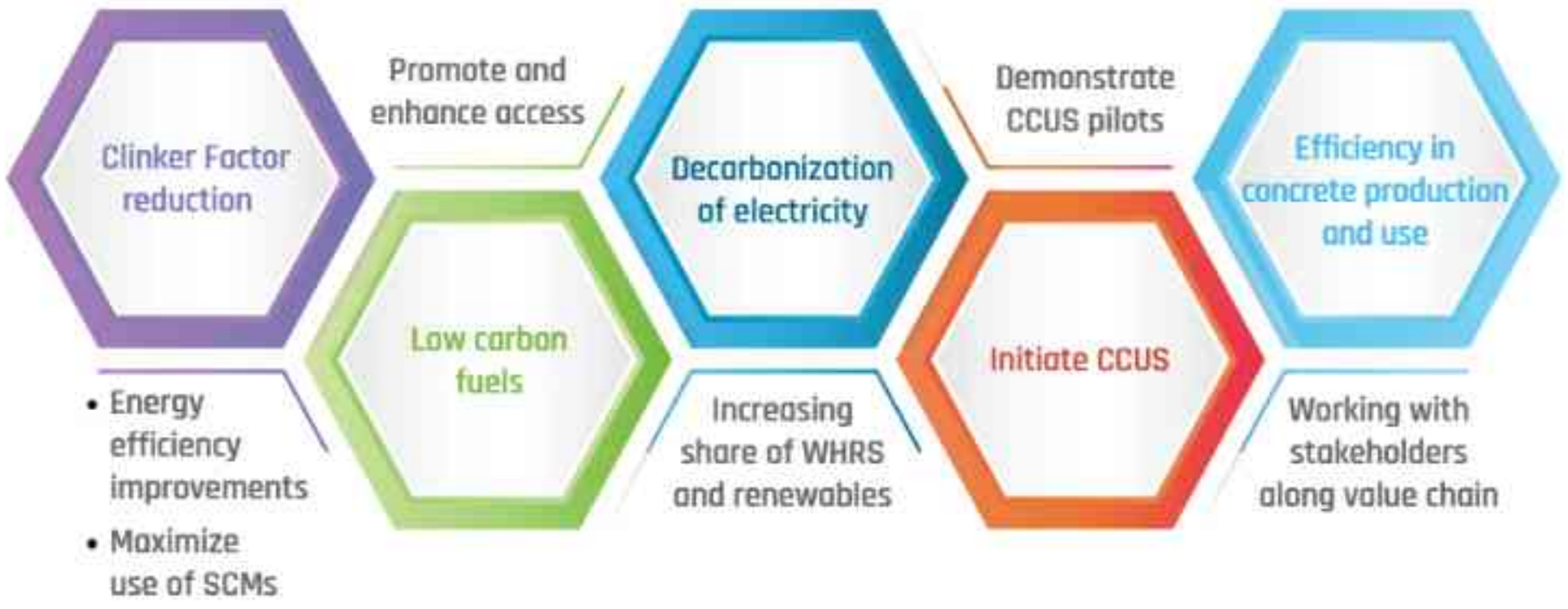


Figure 8: Key actions required for cement sector upto 2047

5 The Path to Net-Zero Emissions: By 2070

In the period from 2047 to 2070, the cement industry envisages acceleration and wide-scale adoption of innovative technologies to achieve net-zero emissions. During this period, it would build on the progress achieved till 2047. It will also be working closely with other relevant sectors in realizing the net-zero goal by 2070.

By 2070, it is envisaged that the Indian cement industry will shift completely from fossil fuels to low-carbon fuels, e.g., biomass, societal wastes with biogenic content, green hydrogen and green electricity. Suitable supply chain networks are likely to be in place for biomass and societal wastes. Innovative technologies such as kiln/calciner electrification, oxy-fuel burner, concentrated solar thermal (CST) applications and newer cement production technologies being developed globally by research and academic institutions like MIT, University of California, Cambridge University, ECRA, VDZ, etc., are still at low Technology Readiness Levels (TRL). These technologies will perhaps get commercialized and the Indian cement industry will also benefit from these global developments.

The Innovandi Global Cement and Concrete Industry Research Network (GCCRN) is a great example of partnership that can help develop and scale such technologies. The Innovandi GCCRN ties together the cement and concrete industry with scientific institutions to drive and support global innovation with actionable research.

Blended cements like composite cement and LC3 and new cement types like Portland Limestone Cement (PLC) will have significant share along with existing cements like PPC and PSC. The share of blended cements will witness an increasing trend. Availability of PPC may be limited by 2070 in certain regions of the country due to envisaged net-zero transition of power sector. Government support is needed towards availability and accessibility of new SCMs and requisite standards for new blended cement types.

India is also likely to see the transition from bag to bulk cement and industrialized ready-mix concrete. The transition to bulk cement should ensure utilization of SCMs with suitable quality control systems. This would help reduce the carbon intensity of the cement (MPP, 2022).

The cement industry will start building up from its achievements till 2047 by adopting newer technologies like CCUS and kiln electrification in the following years. It is expected that the industry will be effectively utilizing commercially available CCUS technologies. Conducive ecosystems such as financing schemes of the government, regulatory clearances and infrastructure such as storage, e.g., common carbon storage facilities (CCSF) and transportation of CO_2 would be necessary for CCUS to flourish. It is further envisaged that nature-based solutions (NbS), e.g., agro-forestry will complement decarbonization efforts with CCUS, which are, however plant and location specific.

6 Decarbonization Levers for Cement Industry

The India cement roadmap identifies the following decarbonization levers to achieve net-zero emissions by 2070 (Figure 9):

1. Clinker efficiency (reducing specific thermal energy consumption)
2. Use of alternative fuels
3. Increased use of Supplementary Cementitious Materials (SCMs)
4. Decarbonization of electricity
5. New binders
6. Carbon Capture, Utilization and Storage (CCUS)
7. Recarbonation (Carbon Uptake)
8. Cement-use efficiency

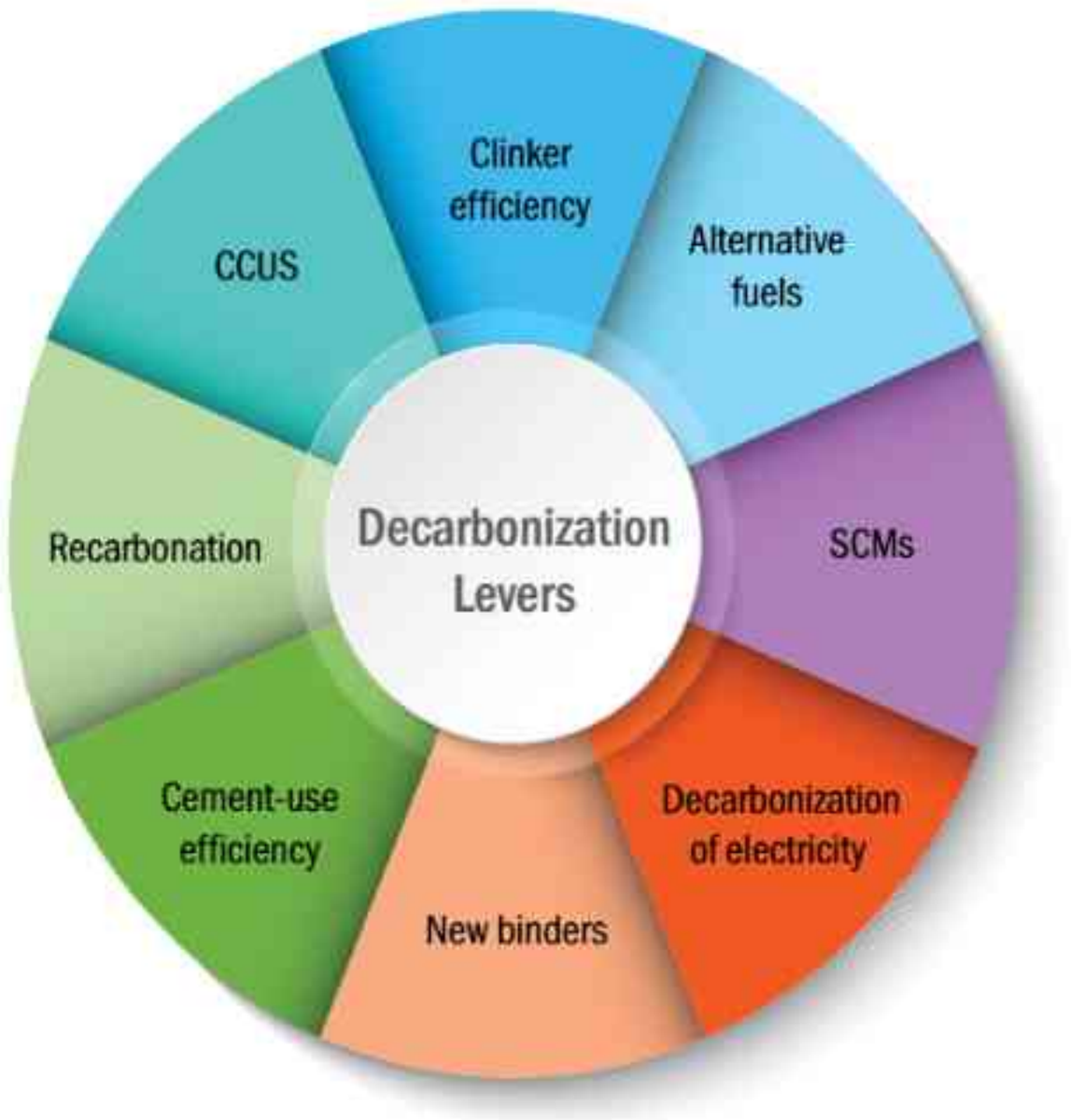


Figure 9: Decarbonization levers

6.1 Clinker efficiency

About 99% of the installed capacity of Indian cement industry uses energy efficient dry kiln process in the production. The Indian cement industry has successfully adopted a range of Energy Efficient (EE) technologies, e.g., process optimization, latest generation of clinker coolers, efficient grinding systems, digitalization, etc. The adoption of EE technologies and practices has enabled the Indian cement industry to improve the energy performance substantially. Although some of the cement plants in India have Specific Energy Consumption (SEC) levels that can be considered to be globally the best, there exists a potential in other plants and with advancement in technology, it is expected that further reduction would be possible in the future.

The average thermal Specific Energy Consumption (SEC-thermal) of Indian cement industry was estimated to be 731 kcal per kg clinker in 2020–21 (Figure 10). The cement industry aims to achieve average SEC-thermal of about 705 kcal per kg of clinker in 2070 which is about 3.6% reduction with respect to 2020 level (Source: stakeholder discussions). This is by taking into consideration the increase in energy consumption due to deployment of CCUS technologies.

In addition, there is a need to put in more efforts to identify potential biomass sources, establish biomass supply chain and use them in substantial quantities in the short to medium term with government support. Further, R&D efforts in areas such as green hydrogen, kiln electrification and other innovative technologies such as solar thermal must be strengthened. These options may become potential and viable decarbonization options in clinker production in the medium to long-term.

This decarbonization lever, i.e., clinker efficiency includes reduction in SEC-thermal, increased use of biomass and adoption of green fuels and technologies as mentioned above.

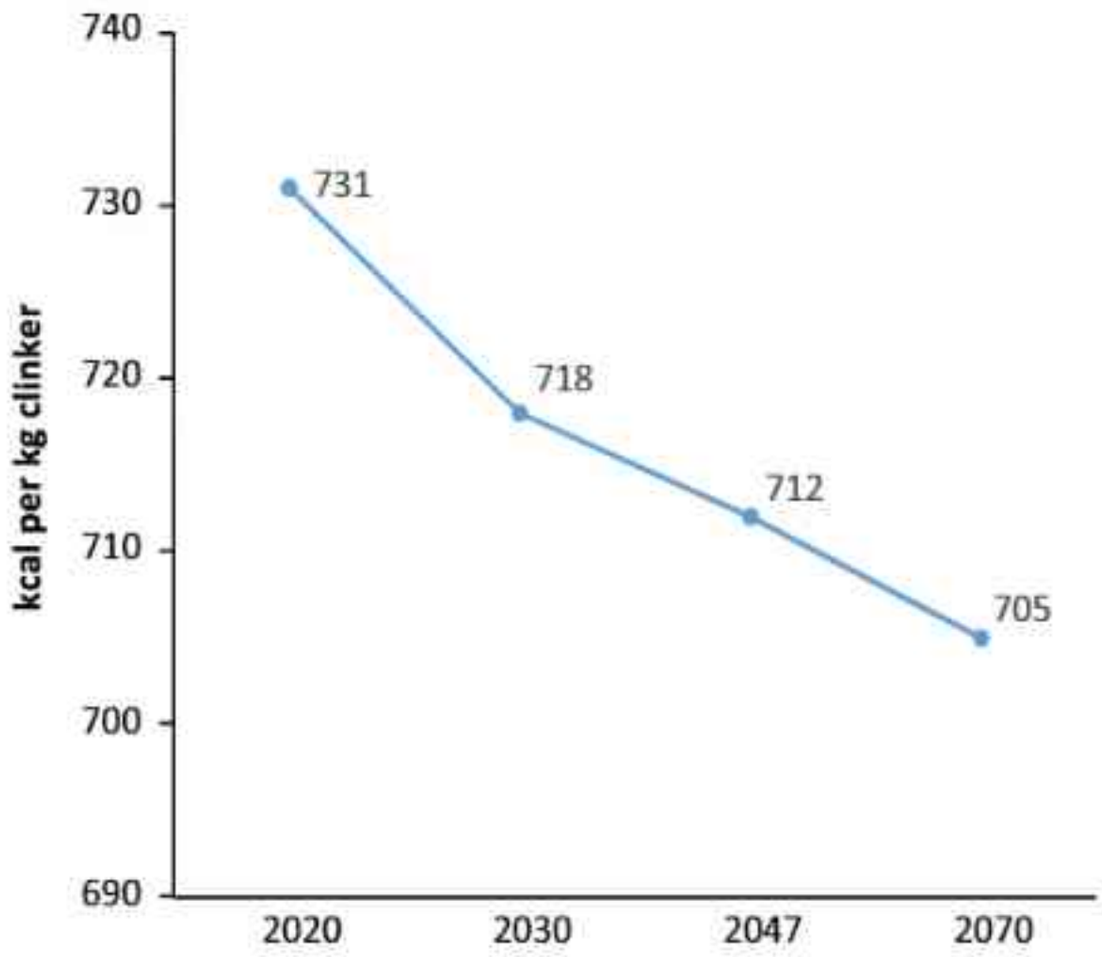


Figure 10: Envisaged trend in SEC-thermal

CO_2 Reduction Potential with Clinker Efficiency by 2070: 11.6%

6.2 Alternative fuels

The level of use of fossil fuels, i.e., coal and petcoke together was close to 95% of thermal energy consumption in 2020. The major cement companies in India are already exploring and experimenting with a range of alternative fuels based on their availability, accessibility, and economic viability, e.g., societal wastes with biogenic content [like municipal solid waste (MSW), plastic wastes, used tyres and industrial wastes] for thermal substitution of fossil fuels. The use of fossil fuel wastes in cement industry would help in reducing country-level emissions (Figure 11).

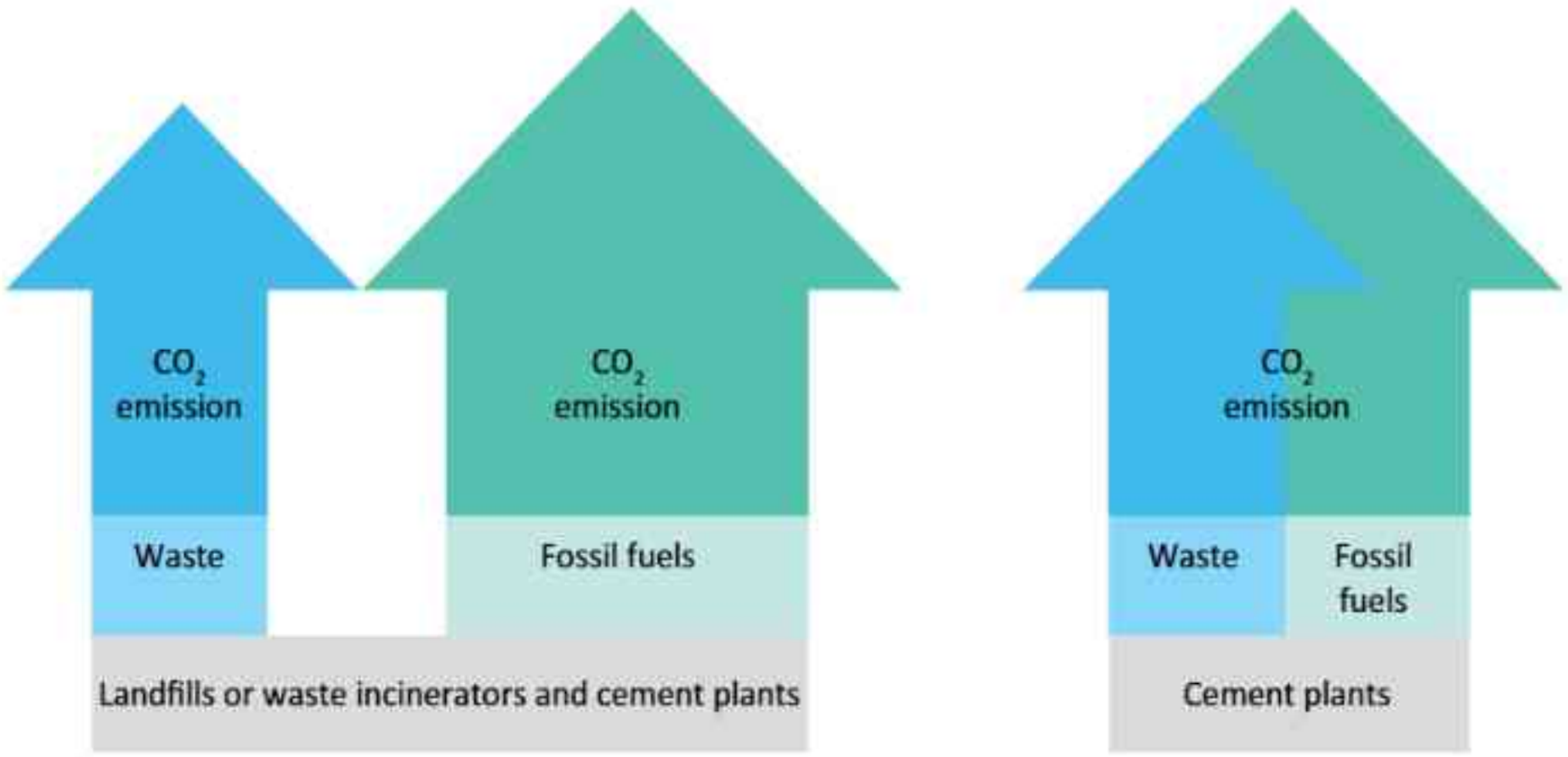


Figure 11: Effect of using fossil fuel wastes as fuel in cement industry

Emissions from pure waste biomass and from the biogenic carbon content of mixed fuels is considered as climate neutral in accordance with the Greenhouse Gas Protocol.[2]

To maximize and optimize the use of alternative (waste) fuels from fossil fuel origin, there is a need to address a range of issues such as availability with consistent quantity & quality, accessibility, collection & segregation, transportation, pre-processing requirements, etc.

It is important to establish a suitable supply chain for this purpose. Segregation of wastes at source is important and critical. For example, the role of urban local bodies is pivotal in source segregation of municipal solid wastes (MSW). Although various preparatory activities for alternative fuel sources would marginally increase electricity consumption, it will be overweighed by gains due to reduced thermal energy consumption, CO_2 emissions, cost economics, etc.

It is expected that the cement industry will be able to replace fossil fuels completely with a combination of low carbon fuel-mix by 2070 (Figure 12). The share of low carbon fuel-mix in the cement industry by 2070 is envisaged to be: green hydrogen/ green electricity (50%), alternative fuels (50%) which include biomass (15%) and alternate fuels from fossil waste origin (35%).

Figure 12: Envisaged trend in low-carbon fuel mix

CO_2 Reduction Potential with Alternative Fuels by 2070: 4.6%

[2] Utilization of waste fuels in cement plants results – according to the Greenhouse Gas Protocol – in CO_2 and even GHG emission reductions at landfills and incineration plants.

6.3 Supplementary Cementitious Materials

The use of SCMs is considered as one of the recognized strategies to reduce environmental impacts of cement industry. The Indian cement industry produced about 73% of blended cement, a combination of fly ash-based PPC, GGBS-based PSC and composite cements in 2021. Fly ash accounts for maximum use in cement industry as compared to other SCMs. About 25% of fly ash produced (~ 60 million tonnes) in India was utilized by the cement industry in 2021–22 (Figure 13). Enhanced use of SCMs will help in reducing clinker factor, thereby reducing thermal energy requirements for a given volume of cement production.

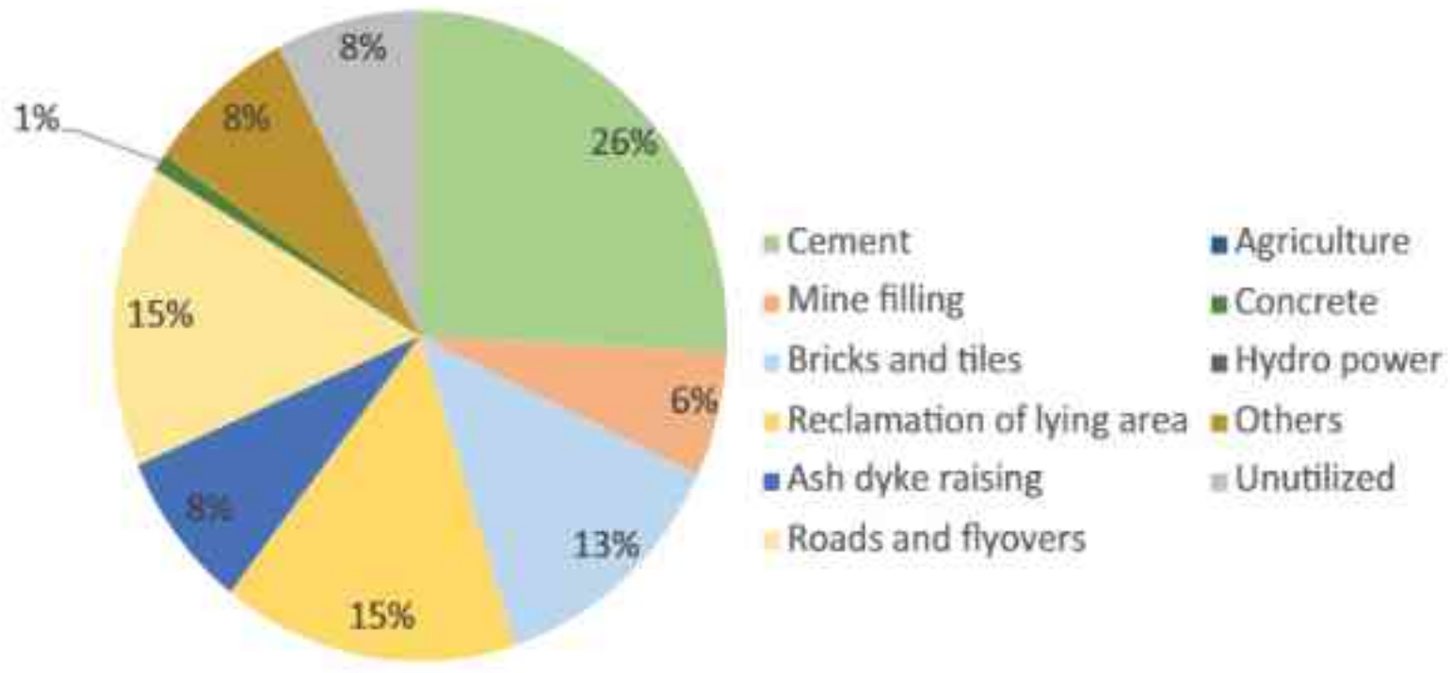


Figure 13: Flyash utilization in 2020–21

With continued increase in cement production over the next few decades, there will be a need to look out for newer and viable SCMs in future. The cement roadmap identifies the following options for enhancing use of SCMs in cement production, thereby minimizing overall production of Ordinary Portland Cement (OPC) (Figure 14).

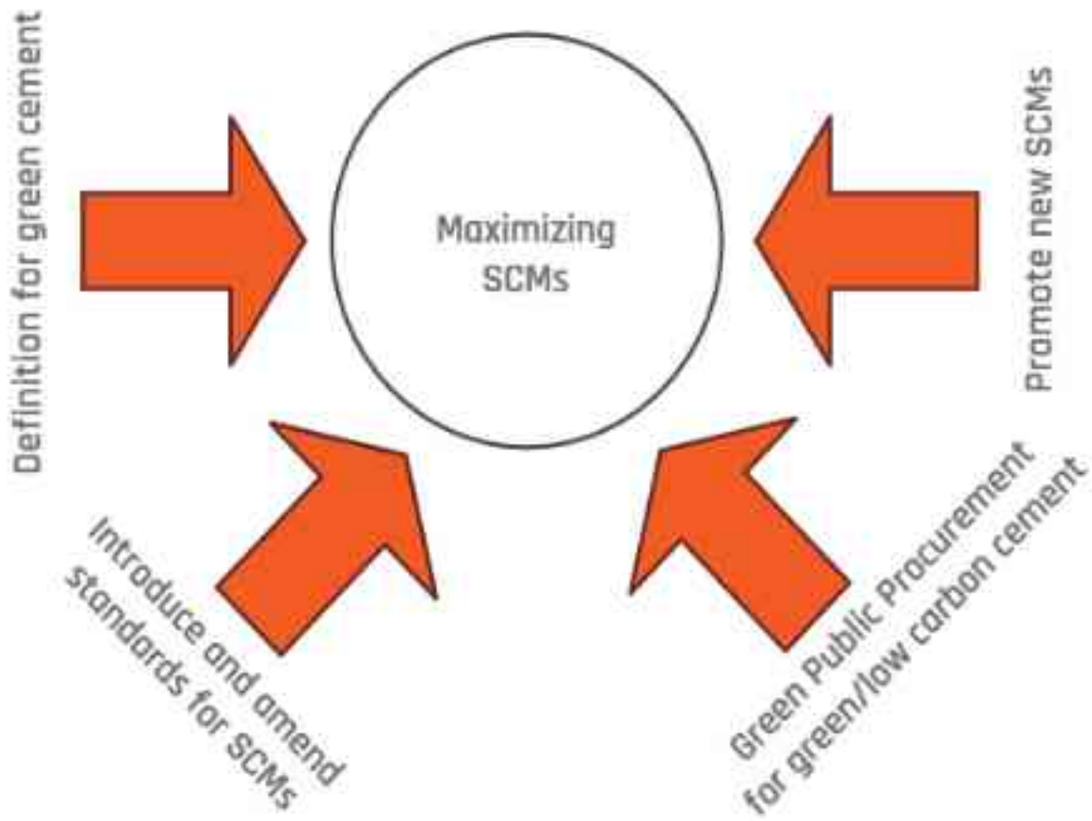


Figure 14: Key components to increase SCM use

- Maximize the use of flyash and continue producing Portland Pozzolana Cement (PPC) (assuming that flyash will continue to be available from thermal power plants equipped with CCUS)
- Maximize the use of GGBS and continue producing Portland Slag Cement (PSC) (assuming that part of the Indian steel industry continues to use blast furnaces equipped with CCUS)
- Enhance production of LC3 and composite cements

- Introduce Portland Limestone Cement (PLC)
- Introduce Performance Based standards for concrete to enhance the use of SCMs
- Introduction of green public procurement for green/low carbon cement

(i) Fly ash utilization

The cement industry will continue to produce PPC based on availability while gradually replacing it with other blended cements such as composite cements, LC3 and PLC. The present level of usage of fly ash in PPC production is 20–32% and can be enhanced upto 35% as per Indian standards[3] for PPC. The roadmap assumes that fly ash generation would continue upto 2047 and perhaps even beyond in 2070 with a few coal-based thermal power plants continuing to operate with CCUS (PSA, 2024). The share of PPC is expected to decline substantially by 2070 from the present level of 64%.

(ii) Maximizing slag utilization

The generation of blast furnace slag in India was estimated to be 34 million tonnes during 2021–22. The slag generation will continue to increase with the expansion of Indian steel industry through Blast Furnace-Basic Oxygen Furnace (BF-BOF) route in the coming decades. The National Steel Policy (NSP) 2017 projects the crude steel production of 255 million tonnes by 2030, of which, 60% production is envisaged through BF-BOF route. The recently released green steel report by the Ministry of Steel also envisages continued use of BF-BOF route for steel production in the coming decades. As a result, slag is likely to remain available for blended cement production. However, the share of PSC is expected to reduce marginally by 2070 from the present level of 7%.

(iii) Promote composite cements

The Indian cement industry produced a marginal 2% composite cement (which uses a combination of fly ash and slag as per BIS standards) in 2020. With continued availability of SCMs (flyash and slag), the share of composite cement is expected to increase substantially by 2070.

(iv) Enhanced use of calcined clay for LC3 cement production

Calcined clay has been identified as one of the potential SCM options to produce LC3 cement, a blended cement which has lower clinker factor. Some of the features of LC3 cement include the following:

Limestone Calcined Clay Cement (LC3 Cement)

The Indian standards on Limestone Calcined Clay Cement, i.e., LC3 cement (IS 18189:2023) having low clinker ratio with both technical and economic advantages was introduced in June 2023. The standards include the requirements of raw materials such as calcined clay, limestone and clinker and the respective proportions which shall be used in LC3 production.

The BIS standards for LC3 cement specifies a minimum of 40% kaolinite in the raw clay used in the manufacture of the calcined clay. LC3 cement must also adhere to various physical properties and chemical properties as stipulated in the standards. For example, the fineness of calcined clay, or the blend of calcined clay and fine ground limestone have to be maintained not less than 600 m^2 per kg, according to IS 4031.

[3] The standards, IS 1489 (Part-1):2015 for Portland Pozzolana Cement stipulates a maximum of 35% use of fly ash in cement manufacturing.

- The clinker content of LC3 cement is lower at about 50%.
- CO_2 emissions from LC3 production are expected to be 30% lower than OPC and 11% lower than PPC based on current rates of fly ash use.

The share of LC3 cement is expected to increase substantially by 2070. However, further in-depth survey and studies by the government are required for ascertaining suitable clay availability in different regions across India.

(v) Use of limestone for PLC production

Portland Limestone Cement (PLC) is a new type of blended cement which may be explored by the Indian cement industry. PLC is presently being produced in countries like Sri Lanka and Bangladesh. PLC uses about 15% of limestone along with gypsum and clinker (Cement Association of Canada, 2023). Suitable standards for PLC production may be introduced, which would help Indian cement industry to explore and produce new blended cements. PLC might also play an important role in 2070 based on its acceptance and utilization in the construction sector.

(vi) Envisaged demand for SCMs

The total fly ash demand for cement industry for PPC and composite cement production is expected to reach close to 295 million tonnes in 2070 (Figure 15). Similarly, the total GGBS demand for cement industry for PSC and composite cement production is expected to reach close to 134 million tonnes in 2070 (Figure 16). The calcined clay demand for LC3 cement production by 2070 would reach about 110 million tonnes (Figure 17).

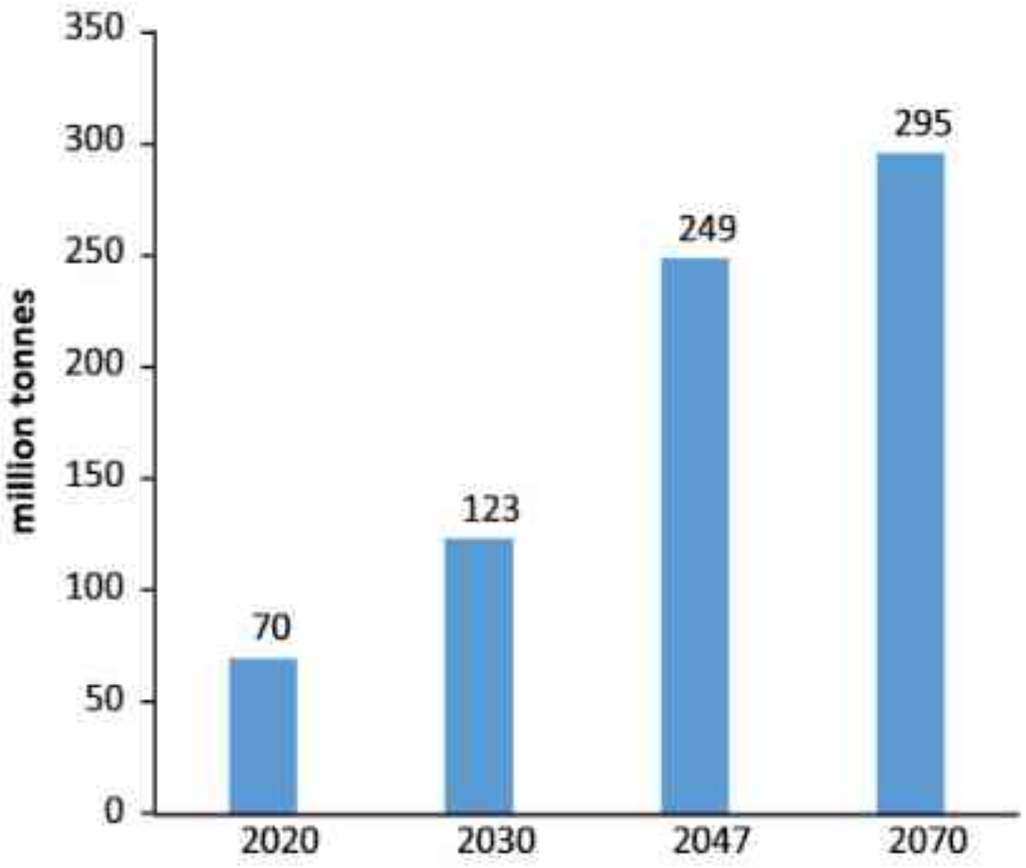


Figure 15: Flyash demand

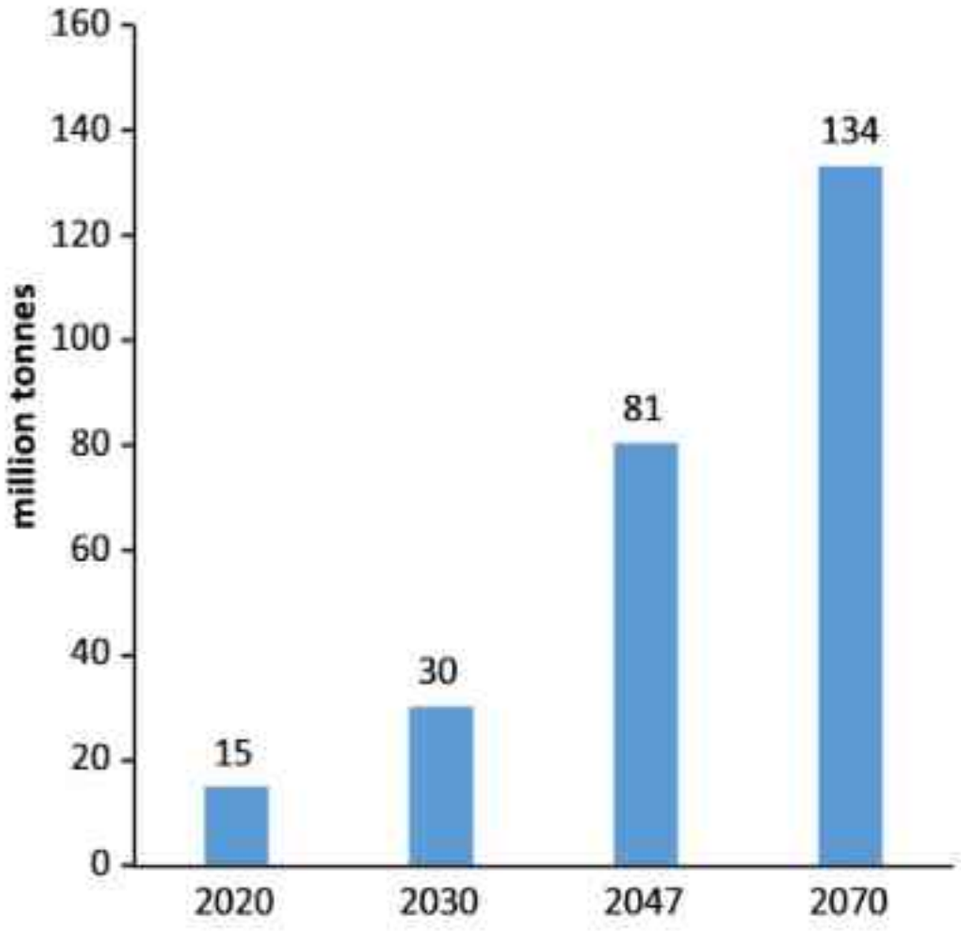


Figure 16: Slag demand

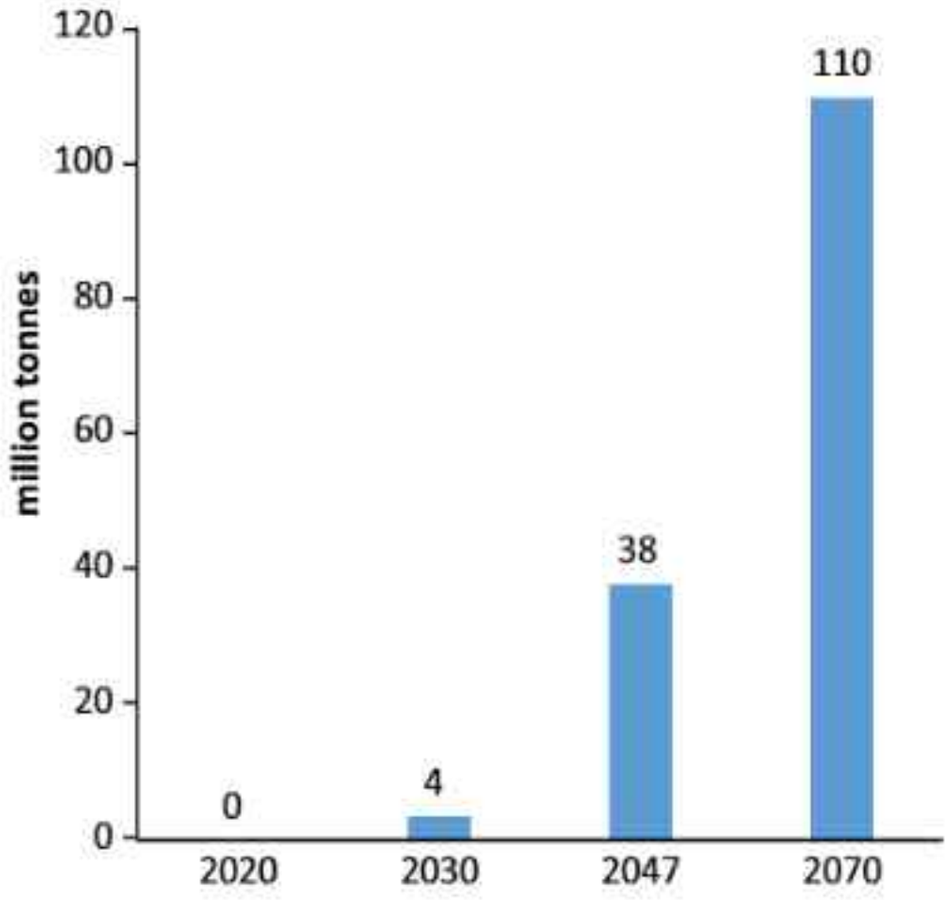


Figure 17: Calcined clay demand

(vii) Share of blended cement projections in 2070

Currently, India is having a low clinker ratio, which is attributed to high share of blended cement usage. It is envisaged that the clinker factor would further get reduced from the present level of 0.75 to 0.56 by 2070. Increased use of existing blended cements as well as new types will help in achieving this ambitious target. As an illustration, this roadmap document assumes that the Indian cement industry would produce close to 90% blended cements of different combinations by 2070 while assuming an overall clinker factor of 0.56 (Figure 18). There will be other ways as well to reduce the clinker factor, e.g., introduction of other cement types and other SCMs.

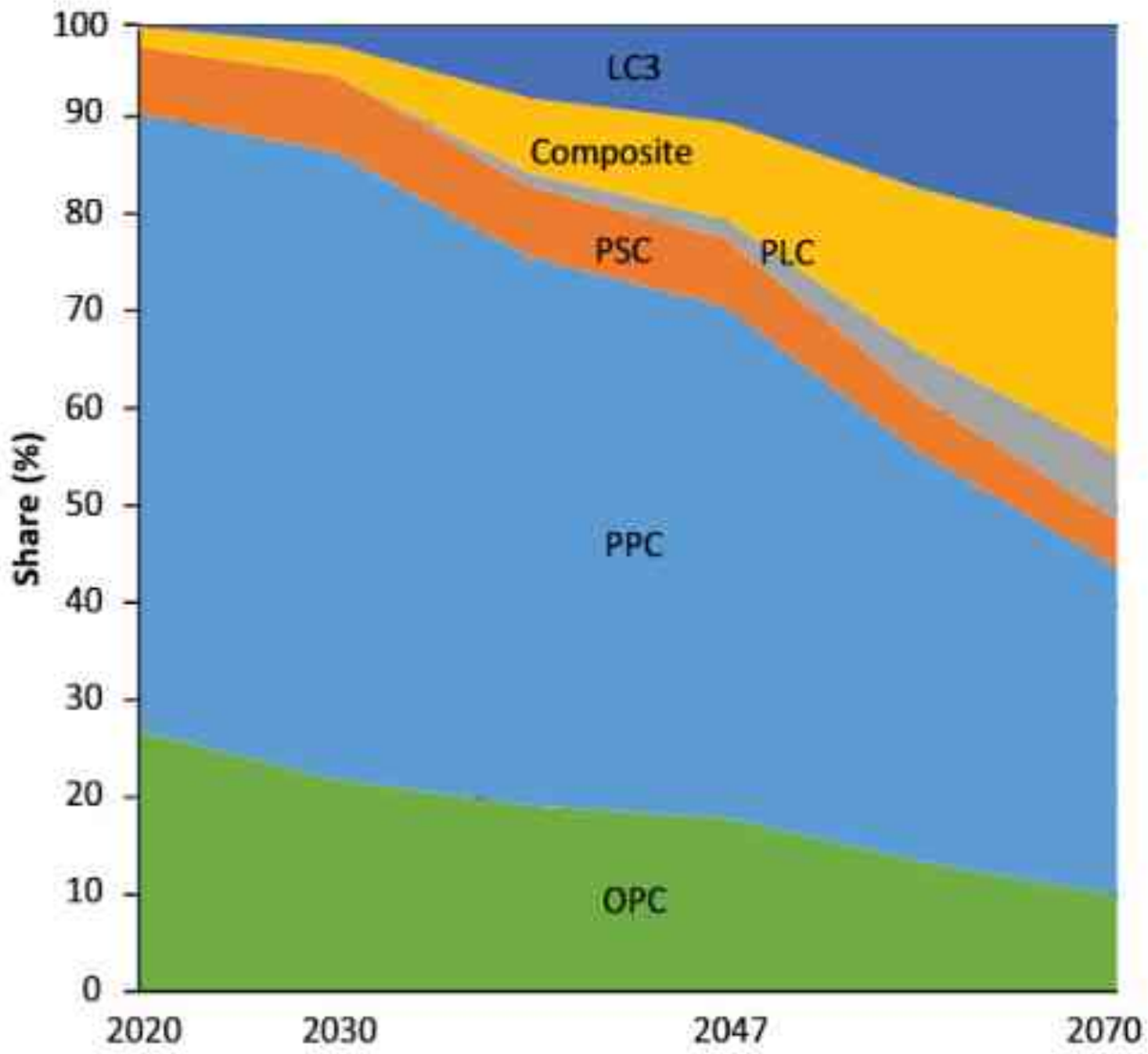


Figure 18: An illustration of envisaged blended cement share for clinker ratio of 0.56 in 2070

The envisaged composition of cement types in India by 2070 is shown in Table 2.

Table 2: Envisaged composition of cement types in 2070

OPC 95% clinker, 5% gypsum	**Blended Cements** **PPC** 55% clinker, 40% flyash, 5% gypsum **PSC** 30% clinker, 65% slag, 5% gypsum **PLC** 80% clinker, 15% limestone, 5% gypsum **Composite cement** 45% clinker, 25% flyash, 25% slag, 5% gypsum **LC3 cement** 50% clinker, 32% calcined clay, 13% limestone, 5% gypsum

Source: Stakeholder discussions

(viii) Clinker factor projection in 2070

The increased share of blended cement would lead to reduction in overall clinker factor of the cement sector. It is envisaged that the clinker factor would decline from 0.75 during 2020–21 to about 0.56 by 2070 (Figure 19). This would further help in improved circularity of waste generation (fly ash, slag, etc.) across different sectors.

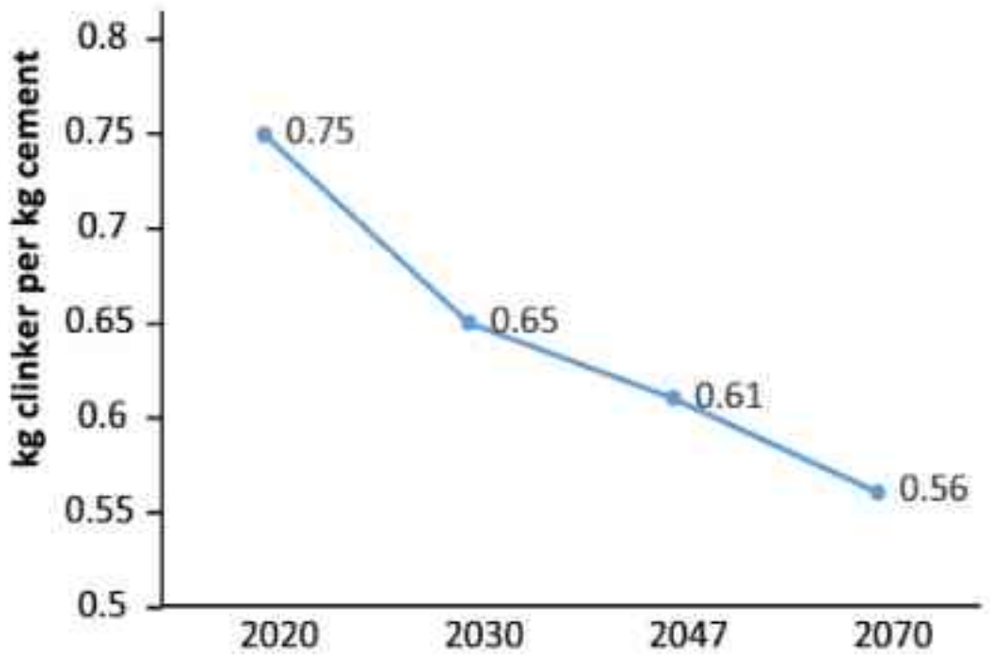


Figure 19: Projected trend in overall clinker factor

CO_2 Reduction Potential with Enhanced Use of SCMs by 2070: 16.2%

6.4 Decarbonization of electricity

At present, about 10% of the cement industry's carbon footprint can be attributed to its electricity consumption in the production process. The cement industry meets its electricity requirements through captive power, waste heat recovery (WHR) system and grid electricity, including, a marginal share of renewable energy; the share of each depends on individual cement plants. The following decarbonization options would help the Indian cement industry move towards decarbonization of electricity.

(i) Electrical efficiency improvements

The average Specific Electricity Consumption (SEC-electrical) of cement plants was estimated to be 73 kWh per tonne cement in the 2020–21 period, which is lower than the global average. However, there is a potential to further improve the overall SEC-electrical performance of cement industry by adopting additional energy efficiency measures, e.g., vertical roller mills (VRMs), high pressure grinding rolls (HPGRs), variable frequency drives (VFDs), high efficiency separators, conveyors, etc., wherever applicable. This would help in reducing overall SEC-electrical to about 65 kWh per tonne cement by 2070 (Figure 20). This is in spite of adopting CCUS and use of green hydrogen as a fuel in the cement industry by 2070.

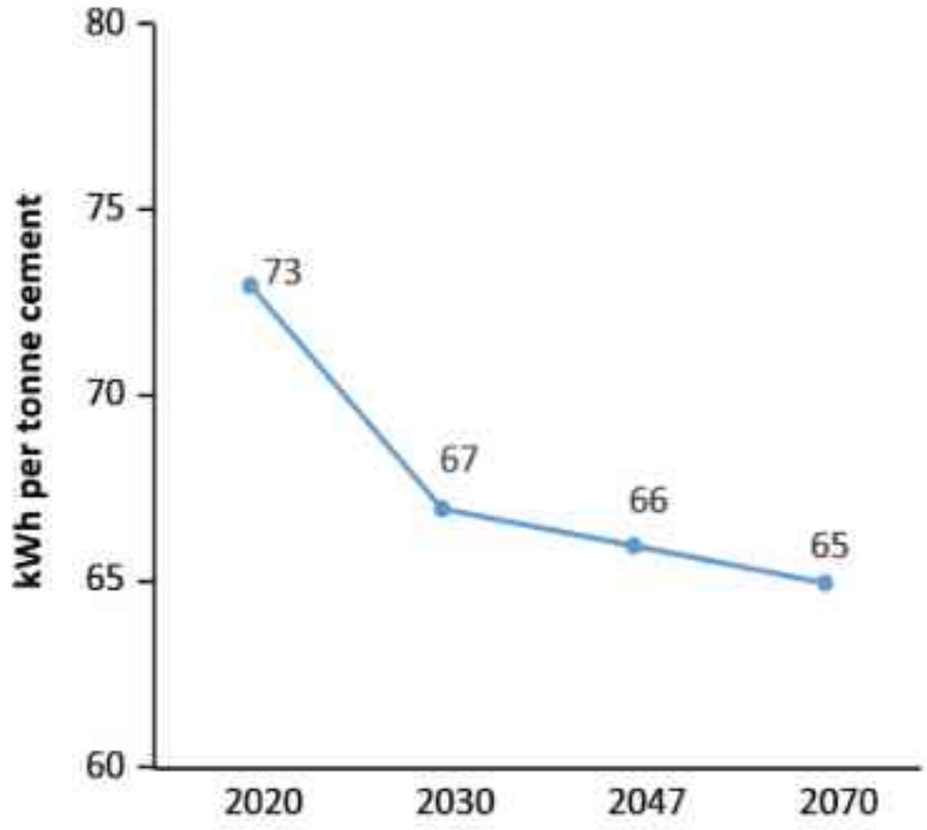


Figure 20: Envisaged trend in SEC-electrical
(Source: Stakeholder discussions)

(ii) Enhancing WHR-based power generation

In a cement plant, nearly 35% heat is lost primarily from clinker production process. In a waste heat recovery (WHR) system, the waste heat is utilized to generate power. In the past few years, the Indian cement industry has made efforts at adopting WHR system to improve energy efficiency and reduce carbon emissions. Many cement plants utilize WHR systems to generate electricity through high pressure steam route. The WHR-based electricity represents about 15% of electricity requirements in Indian cement plants (Industry data analysis, TERI, 2022).

Indian cement industry has already realized upto 50% of the WHR potential, which is approximately 538 MW as against an identified potential of 1100 MW (CMA, 2021). The cement industry would put in efforts to realize the maximum potential, which will help in reducing the dependency on captive power plants or grid electricity. Deemed renewable energy status for the WHR-based power generation by the government would further encourage its adoption in cement plants.

(iii) Shift to green electricity

Indian cement industry is deeply committed to decarbonization of electricity. Many of the cement plants have already started looking at renewable energy either through open access or group captive plants, so as to reduce their dependency on coal-based captive power plants. It is expected that as the power sector decarbonizes, the grid will gradually become greener and Scope-2 emissions as well as emissions from fossil fuel-based captive power plants from the cement sector will reduce significantly. It may also be noted that apart from existing requirements, cement industries would require additional electricity for kiln electrification, CCUS, etc.

CO_2 Reduction Potential with Decarbonization of Electricity by 2070: 6.2%

6.5 New binders

There are possibilities of utilizing new binders such as geopolymers, carbosilicate and calcium hydrosilicate binders. Other examples of new binders include construction and demolition wastes, Reactive Belite-rich Portland Cement (RBPC), Belite Calcium Sulfoaluminate (BCSA) Cement, wollastonite-based cement[4], prehydrated calcium silicate cement, magnesium silicate cement, alkali activated binders, bio-mineralization, etc. (GCCA). Globally, these new binders are under different stages of development. While some have a long history, spanning decades and are already utilized commercially, though not extensively, others are recent innovations or necessitate more extensive research before their actual potential can be gauged.

CO_2 Reduction Potential with New Binders by 2070 : 0.2%

[4] The wollastonite-based cement effectively captures the CO_2 emitted during their production as they set and harden in concrete, creating a low-carbon or carbon neutral construction material.

6.6 Carbon Capture, Utilization and Storage

Carbon Capture, Utilization and Storage (CCUS) is a key lever to tackle process emissions from cement industry and achieve net-zero emissions. However, the Carbon Capture and Storage (CCS) technology options are still under nascent stages of development and not implemented so far in any of the cement industries in India. A set of carbon capture options are available or being tested globally and only a handful of cement companies in India have initiated actions to explore CCUS as an option.

A number of carbon capture technologies are under development globally. Given the early stages of their commercial development and high capex, adoption of CCUS technologies by Indian cement industries will be possible only with substantial financial support from the government or through international climate finance options. It is equally important to plan, develop and establish suitable CO_2 transport and storage infrastructure facilities to effectively handle CO_2 storage and utilization. The CCUS infrastructure will play a vital role in transporting captured CO_2 from industrial facilities to CO_2 storage locations, where it can be safely stored and prevented from entering the atmosphere. NITI Aayog recommends development of 'CCUS clusters' or common carbon storage facilities for large-scale CO_2 storage sites using shared transport infrastructure (applicable for multiple industries including cement), as well as, options for utilizing stored CO_2 to produce low-carbon downstream products (NITI Aayog 2022).

GCCA, Global CCS institute, Clean Energy Ministerial CCUS initiative, Global CCS foundation released a set of reports on CCUS in Indian Cement Industry. The first report named 'A review of CO_2 Hubs and Storage Facilities' highlights Potential CCUS hub ecosystems in India, Transport and storage costs through a techno-economic analysis, and more while the second report 'Policy and Financing Frameworks' addresses areas where current legal and regulatory frameworks in India could be enhanced/developed to support CCUS.

While the carbon capture technologies are not expected to play a significant role in India until the middle of this century, it is important for the cement industries to have more clarity and understanding on various carbon capture technologies through demonstration projects to ensure techno-economic viability. The demonstration projects on carbon capture would help Indian cement industry in (i) identifying suitable carbon capture technology, (ii) matching capacity requirements, (iii) addressing infrastructure setup for transportation, storage and utilization, and (iv) financial implications for the complete value chain.

With advancements in carbon capture technologies and potential demonstration projects being experimented across the world, it is envisaged that the technology/transaction costs for CCS technologies would come down significantly providing affordability to the Indian cement industry for adoption. However, the cement industry would require support towards deployment of new infrastructure facilities for transportation and storage of CO_2 along with additional energy for CO_2 separation and handling.

(i) Nature-based solutions

The Indian cement industry considers nature-based solutions (NbS) as an additional/complementary lever along with CCUS that can help supplement the ongoing carbon capture efforts. The United Nations Environment Assembly (UNEP, 2022) outlines NbS as a cost effective, sustainable, and long-term solution to mitigate and adapt to climate change. It defines NbS as 'actions to protect,

conserve, restore, sustainably use and manage natural or modified terrestrial, fresh water, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits.'

In this context, India is working towards developing an ecosystem-based approach or ecosystem-based adaptation (EbA). The EbA, a subset of NbS, harnesses biodiversity and ecosystem services to reduce vulnerability and build resilience to climate change. NbS is closely linked to India's commitments and targets, including Nationally Determined Contributions (NDCs), National Biodiversity Targets (NBTs) and Sustainable Development Goals (SDGs). Under the Panchamrit targets announced at COP26 in Glasgow, India is committed to creating an additional carbon sink of 2.5 to 3 billion tonnes CO_2 equivalent through additional forests and tree cover by 2030 and to become carbon neutral by 2070 (PIB, 2022).

Cement industry believes that commercialization of energy plantation projects can be implemented across the country in all cement clusters. Comprehensive studies need to be carried out in the limestone clusters to find out the degraded forest available which can be allocated to the cement sector for energy plantation thereby helping in increasing AFR utilization in kiln and CPP. Demonstration projects can be implemented by encouraging the farmers to promote energy plantation which will enhance livelihood opportunities and encourage the supply chain activities like collection, baling and production of biomass pellets.

(ii) Other innovative solutions

Globally, new cement production processes are being developed in research institutes and universities like MIT, University of California, etc. The objective of these research activities is to develop cement or related products with far less CO_2 emissions than existing production route. Any breakthrough in these efforts would substantially alter the net-zero pathways thus, leading to lower burden on options like CCUS. One such initiative is the Cement and Concrete Breakthrough, led by Canada and UAE. This initiative aims to enable countries to share best practices on a range of policies and other measures to decarbonize the cement and concrete sector.

CO_2 Reduction Potential with CCUS Adoption by 2070: 25.1%

6.7 Recarbonation

Recarbonation is a natural process of CO_2 uptake by concrete. It has been considered in carbon accounting in the IPCC 6th Assessment Report (August, 2021). This roadmap uses Tier-1 of IVL methodology which permits 20% of theoretical maximum carbonation value of 525 kg CO_2 per tonne clinker for recarbonation. Therefore, the Indian cement roadmap considers a reduction of 105 kg CO_2 per tonne clinker due to the natural recarbonation. It may be noted that any modification in assessment methodology for natural recarbonation would have impact on CO_2 reduction potential.

The forecast suggested in this document is intentionally kept conservative as work is still in progress on more detailed evaluation of the recarbonation process. One of the examples that may be quoted here is a country-specific recarbonation study, being supported by the Government of United

Kingdom. Similar studies need to be undertaken in India to establish India-specific carbonation value considering natural recarbonation process. The India-specific study would require support from the government as well as key stakeholders. GCCA India is currently working with Technology Information, Forecasting & Assessment Council (TIFAC) and NCB to calculate the recarbonation (carbon uptake) potential of India.

CO_2 Reduction Potential with Recarbonation By 2070: 5.9%

6.8 Cement use efficiency

In 2020, about 79% of cement dispatched from cement companies was bagged cement. It is projected that there will be a shift from bagged cement to bulk cement (ready-mix segment) with the advancement in the construction practices. Based on industry estimates, about 65% of the cement production is used in concrete making for structural applications of which 29% is consumed by ready mix plants while 36% is mixed at site. The balance 35% of cement produced is used for non-structural applications.

The shift from site-based concrete mixing methods to industrialized concrete production techniques in the construction industry holds significant potential for reducing carbon emissions associated with cement use (Figure 21). By transitioning to ready-mix solutions and centralized batching plants, we can achieve more precise control over material proportions, which enhances the overall efficiency of cement utilization in concrete making.

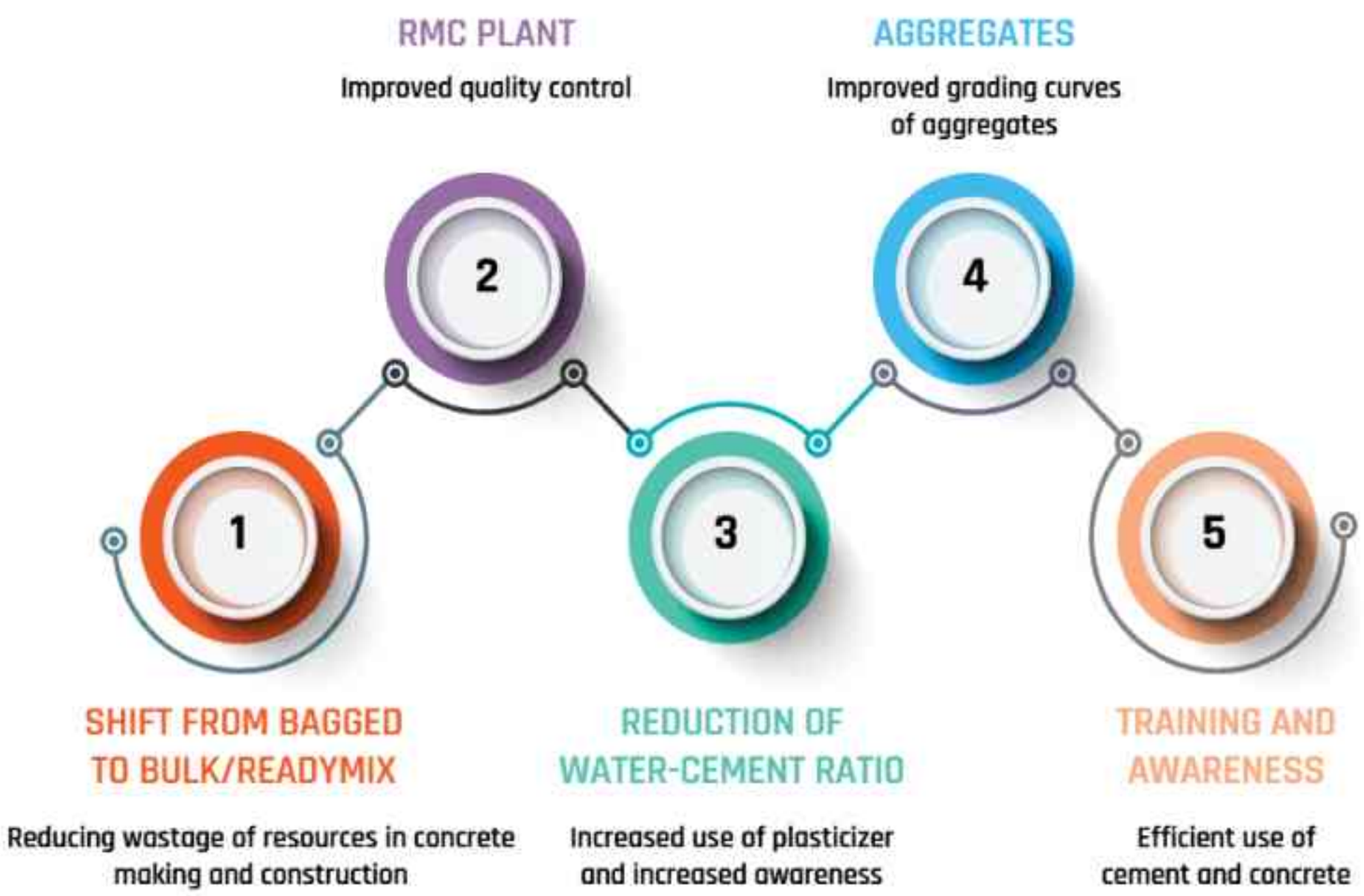


Figure 21: Levers for efficiency gains in concrete production

This will help in adhering to specifications and quality while maintaining optimum performance of concrete in building and construction. The quality of aggregates also helps in increased workability, reduced segregation, reduced cracking, and decreased cement content. This would ultimately help in efficient cement use in concrete (Figure 22). Therefore, optimization of cement in concrete mix is an essential component.

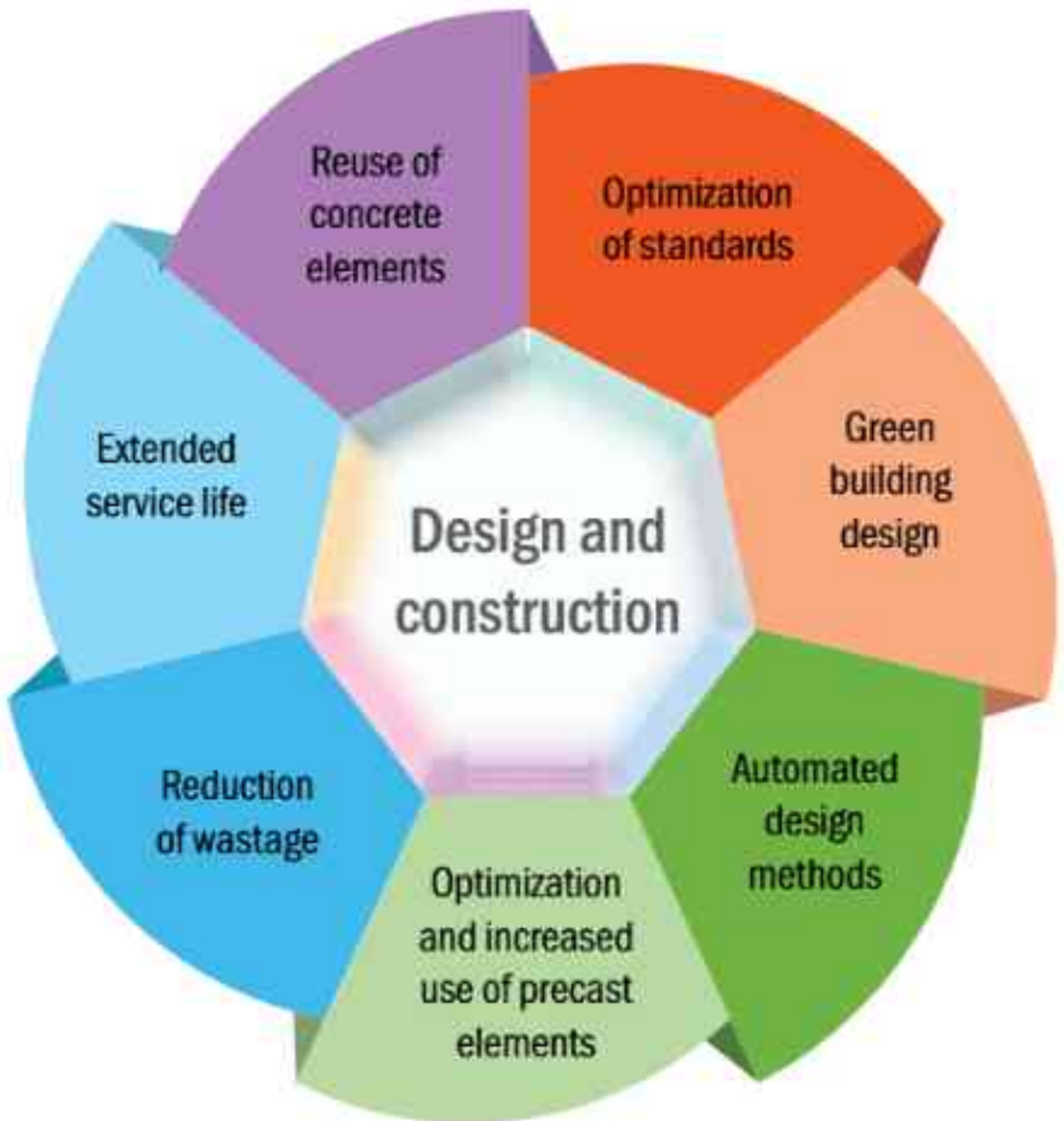


Figure 22: Key decarbonization levers for design and construction

With developments taking place in construction sector, efficiency improvements will occur in concrete production, design and construction sector. The cement industry envisages about 18% improvement by 2047 and 30.2% improvement in cement use efficiency by 2070. This implies corresponding reductions in overall societal demand. The potential areas of improvements in cement end-use efficiency would include the following:

- Increased use of precast materials
- Shift from bricks to Autoclaved Aerated Concrete (AAC) blocks
- Replace cement mortar by adhesives in tiles and block adhesives
- Shift from volumetric method to weighing type at project sites for mixing of cement, sand, and aggregates to prepare concrete
- Waste reduction at construction sites
- Promote suitable Construction and Demolition (C&D) waste management for reuse of co-recycled aggregates without compromising on performance of building structures
- Use of 3-D printing to address complicated structures
- Optimize of concrete floor slab geometry, concrete column spacing, etc.

- Amending specifications and standards of blended cement for non-structural applications, e.g., flooring and plastering
- Pre-engineered buildings, composite structures, pre-stressed structures, and pre-cast construction
- Increased weightage of embodied emission of a building under green building certification

CO_2 Reduction Potential with Cement Use Efficiency by 2070: 30.2%

6.9 Share of decarbonization levers

The share of decarbonization levers in reducing CO_2 emissions in cement industry to achieve net-zero by 2070 is shown in Figure 23.

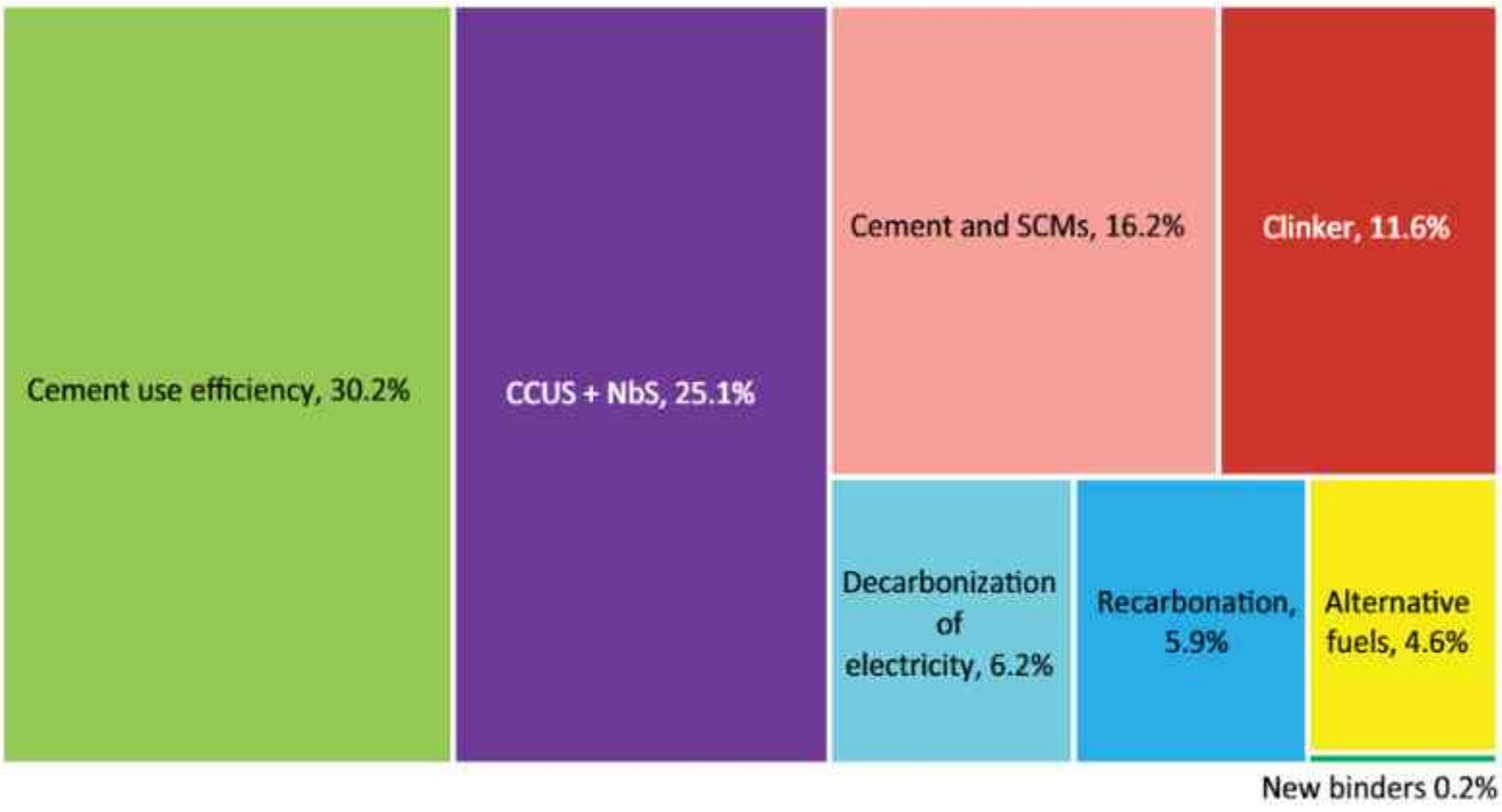


Figure 23: Share of decarbonization levers in cement industry (2070)


5A
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South Indian

7 Role of Public Policy and Enabling Ecosystem

Indian cement industry has been very proactive in adopting advanced technologies and practices that have contributed in making it one of the most progressive sectors globally. The industry has already been able to achieve significant reductions in emissions intensity. The average emissions intensity of Indian cement sector was estimated to be 0.68 tonne CO_2 per tonne of cement during 2020 (Industry data analysis, TERI, 2022). This also represents the baseline emissions intensity for this roadmap document. It is envisaged that the emissions intensity would reduce to 0.56 tonne CO_2 per tonne of cement in 2030 and 0.51 tonne CO_2 per tonne of cement in 2047 while also achieving net-zero by 2070. However, the journey towards net-zero emissions cannot be accomplished on its own; it would require an enabling ecosystem and accompanying policies that promote further reduction.

Compliance to PAT scheme and proposed CCTS regime

Cement industries with a minimum annual energy consumption threshold (30,000 tonnes of oil equivalent (toe) for Integrated cement units and 10,000 toe for cement grinding units) are included as designated consumers (DCs) under the Performance, Achieve and Trade (PAT) scheme of the Bureau of Energy Efficiency (BEE), Ministry of Power, Government of India. The cement industry has been part of various PAT cycles since the inception of the scheme in 2012. Out of 206 cement plants in India, 186 plants have already been covered under PAT upto sixth cycle.

The Indian cement industry has remained a forerunner in improving its energy performance. It has been able to overachieve the mandatory energy reduction targets during each PAT cycle. In PAT cycle-I, cement industry overachieved the target by about 82%; in PAT cycles-II & III, it had overachieved by about 48% and 66%, respectively. It has been estimated that the cement sector has realized a monetary saving of about ₹9,500 crore (USD 1138 million) in PAT-I cycle, and ₹30,000 crore ($3593 million) in PAT-II cycle (CMA, 2022). Thus, the cement industry is moving progressively in its energy efficiency path. In line with the establishment of framework for the Indian Carbon Market (ICM), the cement sector would also be transitioning to the proposed Carbon Credit Trading Scheme (CCTS).

The National Framework for the ICM will use a national carbon credit electronic platform being developed to meet the climate goals of India. The framework comprises (i) Compliance mechanism to address the emissions from energy use and industrial sectors and (ii) Offset mechanism to incentivize the voluntary actions from entities (not covered under compliance) for GHG reduction, thus providing a comprehensive approach to decarbonization of the economy. CCTS was notified in June 2023 and cement is one of the sectors covered under CCTS.

Emissions considered under CCTS include (i) direct emissions from combustion of fossil fuels, (ii) emissions from process and (iii) indirect emissions from electricity purchased from grid & emissions from electricity and heat imported from outside plant boundary. GHG emission intensity targets within 2025–28 will be calculated on the basis of emission related to sources (i) and (iii); subsequent targets will be calculated based on (i), (ii) and (iii).

A strong collaboration and synergistic relationship between the cement industry and the government will be needed for transition to a net-zero economy. The role of government is vital in the net-zero transition process. Following are some of the key policy asks that would support this process:

7.1

Establish a definition for low-carbon cement

Defining low carbon/green cement is crucial for differentiating between cement types and is a key step in advancing green procurement. Developing and implementing unified standards and definitions for low and near-zero emissions cement production is essential. This definition should be developed in consultation with the cement producers, end-users and other stakeholders.

GCCA India is working to create India-specific definitions for low-carbon cement and concrete. Establishing India-specific definitions will aid in the decarbonization of the sector and promote the use of low-carbon cement and concrete.

7.2

Supply chain for alternative fuels

The major alternative fuels include societal wastes (e.g., MSW) and biomass. The policy asks are primarily linked to address availability and accessibility of the alternative fuels while ensuring their economic viability.

(i) Societal wastes

There has been an increasing interest by many cement plants in the adoption of alternative fuels to reduce dependency on fossil fuels, decrease carbon emissions, and promote sustainable development. The alternative fuels being explored and used by the Indian cement plants include waste-derived fuels like MSWs, used tyres, plastic wastes, etc., these alternative fuels would, however, require pre-processing to use them in the production process. These waste-derived fuels, known as Refuse-Derived Fuels (RDFs) or waste fuels of fossil origin, are co-fired along with conventional fuels, which helps to reduce plant-level emissions. The cement industry requires a robust supply chain network for alternative fuels for sustainable use. A tipping fee to the cement industry for pre-processing of the waste can act as an incentive for its enhanced use.

Government may facilitate mapping and inventorization of alternative fuels available in different parts of the country which will benefit the cement industry in planning and utilization. Further, prioritizing RDF for cement industry by the municipalities and city administrations would boost circularity and support the low carbon development strategies in India. Similarly, prioritizing availability of hazardous and non-hazardous wastes for co-processing in cement kilns would benefit both the cement industry and waste management authorities.

(ii) Enhanced utilization of harvested biomass

Some of the cement plants have started using agro-waste in the kilns, although to a limited extent. However, harvested biomass can act as an important energy source to partially substitute fossil fuels. To increase the uptake of biomass as an alternative fuel, key aspects of the circular bio-economy need to be addressed together with necessary policy-level interventions (Ravi Teja Kusuma, 2022). Land availability for captive biomass generation is a key challenge. Therefore, any policy intervention

that addresses this crucial aspect would go a long way in supporting the adoption of biomass as a partial replacement of coal for thermal energy requirements.

7.3 Standards for SCMs

Increased use of 'Supplementary Cementitious Materials' (SCMs) is an important lever for decarbonization of cement industry. The following are the policy asks to enhance SCM use in cement industry:

(i) Amending BIS standards for enhancing fly ash use

The Bureau of Indian Standards (BIS) currently defines suitable cement types for various applications. It provides guidance for maximum allowable SCM content. The standard IS 1489 (Part-1):2015 for Portland Pozzolana Cement (fly ash-based) (BIS, 2015), specifies that the fly ash constituent shall not be less than 15% and not more than 35% by mass of Portland Pozzolana Cement. The options to increase SCM utilization include raising the existing limits of SCM (i.e., fly ash) blending in specific cement types and/or broadening the approved applications for existing cement types.

Discussions with stakeholders indicate that the share of fly ash can be further increased without compromising on the quality of cement. There is a need to encourage performance-based standards instead of prescriptive standards. This would require a revision of existing BIS standards for using fly ash as SCM. Suitable process for amending the existing BIS standards for enhancing fly ash limits can be initiated by involving all the stakeholders.

(ii) Introduce standards and promote new blended cements

The BIS has already introduced standards for LC3 cement. There is also a significant potential for other blended cement types such as PLC. It may be noted that PLC is already being used and standards are available in countries such as Canada, Sri Lanka, and Bangladesh. The process for developing standards for PLC may also be established in India. The government to also promote and enhance the use of blended cement types such as LC3, PLC, composite cement, etc. This would help complement the existing blended cements and reduce the share of OPC by engaging with construction companies and large builders, encouraging them to start using these newer varieties of blended cements.

(iii) Infrastructure and freight subsidy for SCMs

There are a number of cement plants which are located away from the sources of fly ash or slag. For those plants, a freight subsidy for transportation of SCMs beyond 200 km radius could encourage increased uptake of SCMs. Further, there is a need to strengthen infrastructure for bulk transportation of fly ash and slag wherever required. Priority allocation of flyash to the cement industry can further boost its utilization.

7.4 Low carbon cement procurement policy

The public procurement of low carbon/green cement would send an important demand signal to the supply chain, i.e., the cement producers. The government may consider adopting low-carbon procurement on publicly funded projects, thereby, ensuring demand for low carbon cement. One

of the first steps in low carbon cement procurement policy could be to promote enhanced use of blended cements in government funded infrastructure and housing projects. This would require suitable amendments in the bill of materials used by various government departments.

7.5 Geological mapping of clay reserves

The cement sector needs to increase investment into new SCMs such as calcined clay and alternative cement chemistries, to supplement existing SCMs and enable further reduction of the overall clinker ratio. Utilization of calcined clays relies on clay deposits that are geographically spread across the country. The government needs to undertake a detailed geological mapping of clay reserves in India to establish the availability and accessibility of clay for cement industries. The mapping may also consider parameters such as the chemical and physical properties of the new SCMs.

7.6 Long-term policy support for CCUS

The Indian cement industry needs to rely upon Carbon Capture, Utilization and Storage (CCUS) technologies to achieve net-zero as significant emissions are contributed due to process reactions.

From the industry perspective, Carbon Capture and Utilization (CCU) could be a preferred option compared to CCS. In any case, the cement industries will require suitable subsidies towards the implementation and adoption of both CCU and CCS projects. Further, the industry would initially require financial and policy support to conduct detailed studies for developing suitable CCU/CCS projects. In addition, it will be a prerequisite to have long-term legal certainty for CO_2 storage and transportation facilities as significant investments would be involved in establishing such facilities and needs to be set up by the government.

For CCUS to take off, the government will need to develop essential infrastructure for key industrial sites, primarily focusing on CO_2 storage facilities. The geological storage facilities for CO_2 may require substantial land areas. Public acceptance of land-based storage facilities will also be a key factor. It is equally important to develop appropriate tools towards 'Monitoring, Verification and Accounting' for CO_2 storage system; this may include tools for monitoring the volume of CO_2 stored as well as for preventing leakages and its release from storage sites (NITI Aayog, 2022).

7.7 Ensure cement-use efficiency

Cement-use efficiency is an important decarbonization lever when looking at the cement and concrete sector together. The main areas include various opportunities for efficient concrete production and optimizing design & construction. Some of the specific areas are covered in Section 6.8.

7.8 Establish strategic green financing

Decarbonization technologies such as CCUS are quite expensive today. Similarly, other new technologies, such as kiln electrification, green hydrogen-based kilns, pre-processing of low-carbon fuels, processing of new binders, etc., would also require significant investments by the cement

industry. A strategic green financing programme will be vital to support the transition process in Indian cement industries. It could include the provision of operational subsidies, such as viability gap funding, tax credits, and direct capital grants for the first few projects. The government may also allocate funding for conducting feasibility studies on the proposed net-zero technologies, such as CCUS, green hydrogen, kiln electrification, etc.

7.9 Technology, innovation and research & development

The Government of India should encourage Research & Development (R&D) and knowledge-sharing efforts to expedite a range of pilot and demonstration projects on low-carbon technologies through dedicated R&D funding programmes. These initiatives should encompass various deep decarbonization technological solutions like CCUS, Concentrated Solar Thermal (CST) applications and low-carbon fuels (e.g., bio-energy, green hydrogen or electrification). The use of green hydrogen, along with other alternative fuels, has a vast potential for reducing fuel-related CO_2 emissions from the cement industry (ECRA, 2022). Green hydrogen is seen as one of the key energy options for the decarbonization of the industrial sectors, including cement. The substitution of fossil fuels with green hydrogen would help in a significant reduction in CO_2 emissions associated with fuel use in cement production. The pricing of all these low-carbon fuels must be comparable with existing fuels for the envisaged fuel shift and their commercial uptake by the cement industry.

8

Decarbonization Roadmap 2070 for Indian Cement Sector

The total cement production in India in 2019–20 was 334 million tonnes (Industry data). Majority of the cement is consumed as bagged cement with the other consumption segments being Ready-Mix Concrete (RMC), precast and mortar. In line with the 2070 Net-Zero commitments of India, the Indian cement industry aims to achieve net-zero CO_2 emissions by 2070 (Figure 24).

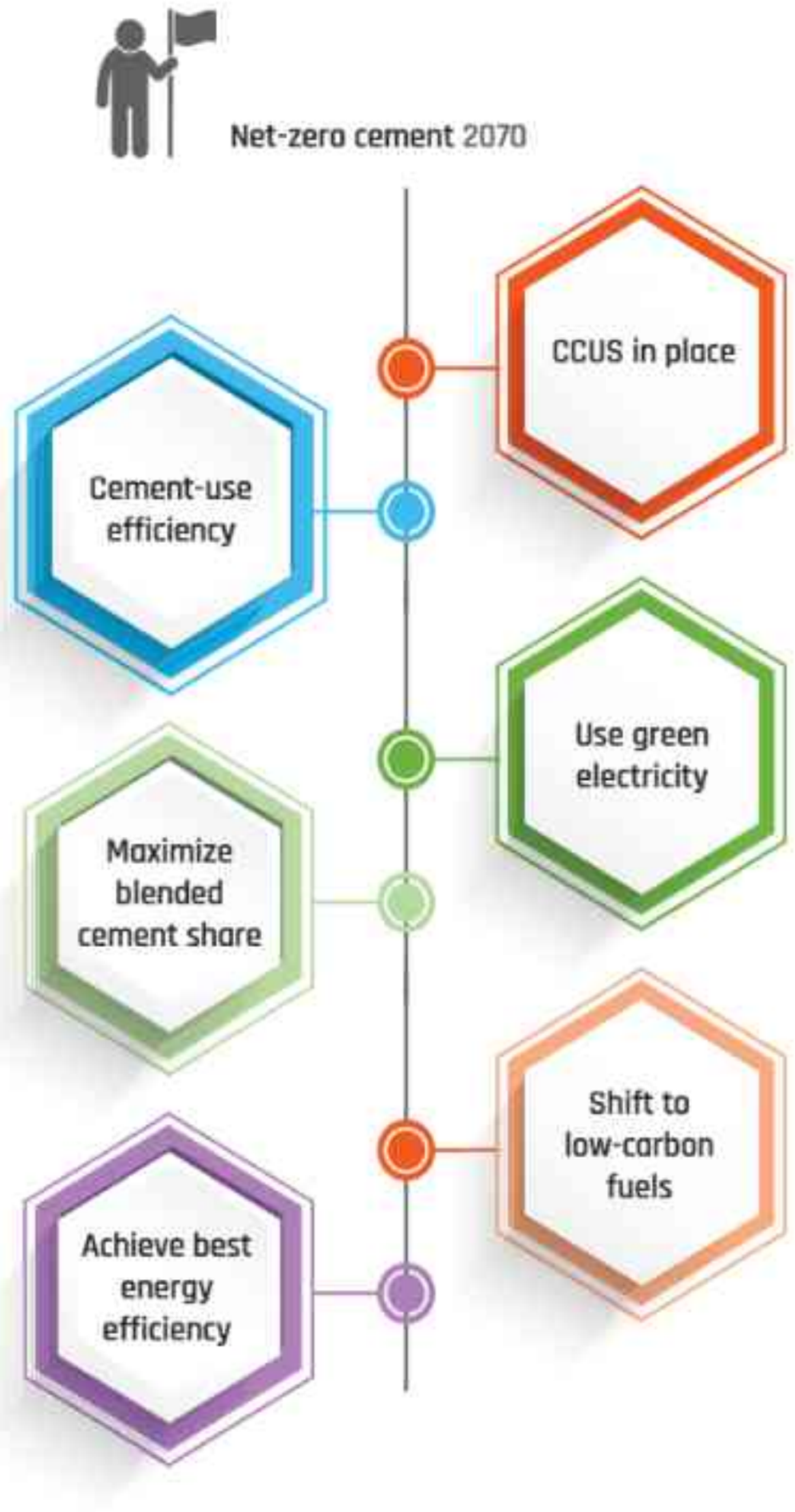

Figure 24: Net-zero CO_2 cement 2070

The cement sector decarbonization roadmap 2070 projects the share of bagged cement would reduce from 79% in 2020 to 46% in 2070 while the share of Ready-Mix Concrete (RMC) would increase from 18% in 2020 to 40% in 2070. The shares of precast and mortar segments are also expected to witness an increasing trend. The bagged cement includes in-situ/precast consumers. Site-based precast is considered in Ready-Mix Concrete (RMC) plants for large infrastructure projects. The estimated per capita consumption of cement in India would reach close to 877 kg in 2070 (Figure 25). The clinker factor would reduce from 0.75 in 2020 to 0.56 by 2070 with increased production of blended cement.

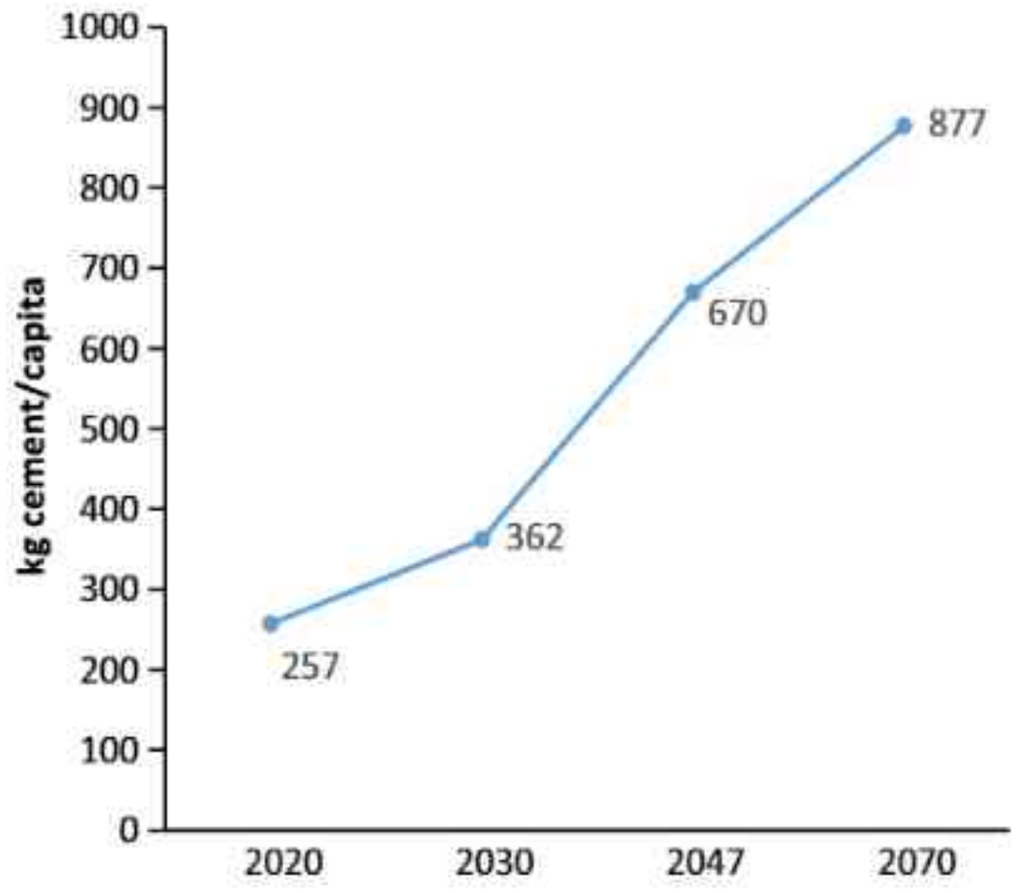

Figure 25: Envisaged trend in per capita cement consumption

8.1 Major assumptions

The major assumptions considered for developing the decarbonization roadmap are as follows:

(i) Cement demand projections

The roadmap assumes an optimistic CAGR of 6.0% for 2020–30 period, 4.5% for 2030–2047 period, and 2.3% for 2047–2070 period to meet the societal cement demand. This corresponds to a cement production of 597 Mt in 2030, 1440 Mt in 2047 and 2278 Mt in 2070 in a business-as-usual (BAU) scenario. Under the decarbonization scenario, the cement demand would reduce to a level of 1546 Mt in 2070 due to better cement-use efficiency in the construction sector. The reduction in cement demand has been considered, assuming an improvement in cement-use efficiency of 6.9% by 2030, 18% by 2047 and 30.2% by 2070 (Figure 26).

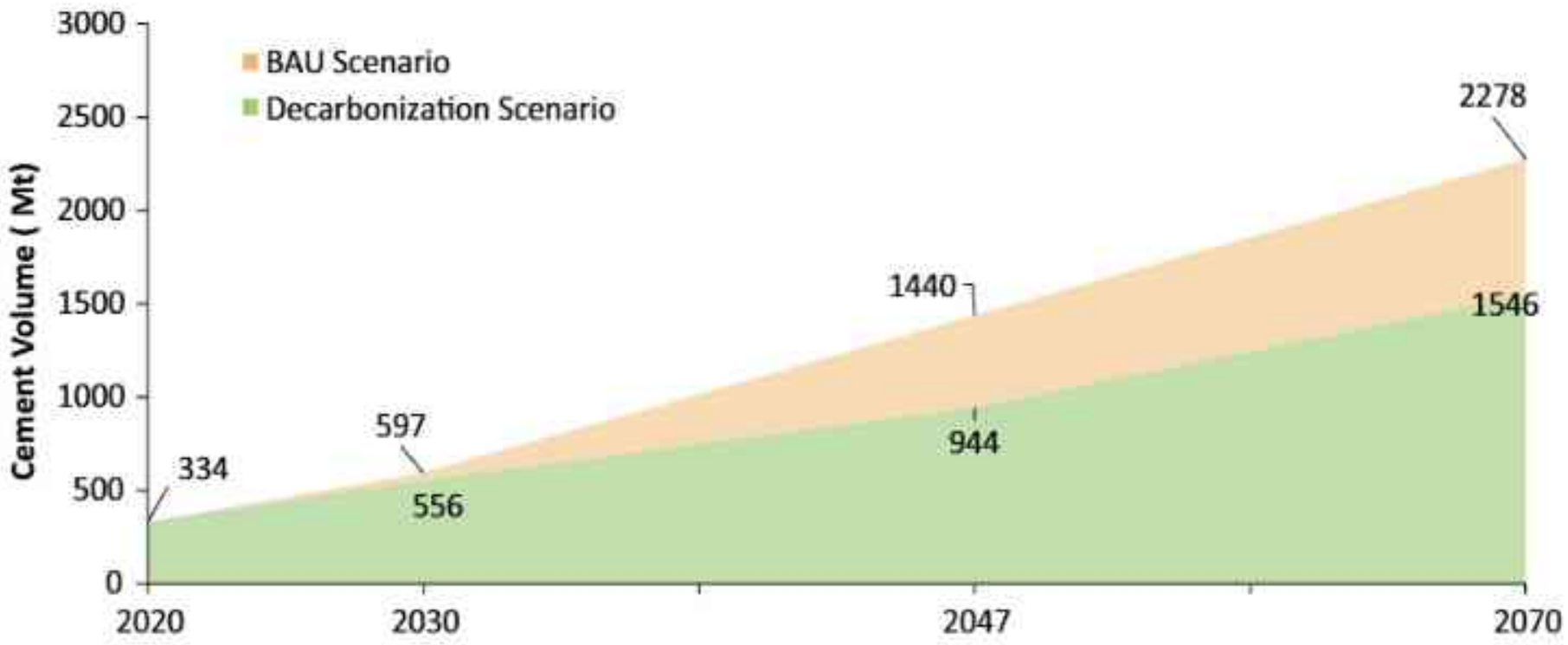

Figure 26: Cement demand projections

(ii) Shift to net-zero fuel mix

The fuel mix share will shift from 95% fossil fuel mix presently to 100% net-zero fuel by 2070. This would include a mix of about 15% share from biomass and a 50% share of a combination of green hydrogen and green electricity. Further, the roadmap assumes the utilization of societal wastes by about 35% in 2070.

(iii) Reduction in clinker factor

The clinker factor would reduce from 0.75 in 2020 to 0.56 in 2070 despite a significant reduction in the availability of fly ash for blended cement production. However, this is expected to be compensated by the introduction and enhanced production of other blended cement types such as LC3 cement, PLC and composite cements. It is assumed that sufficient quantity and required quality of different SCMs like fly ash, slag and calcined clay will be available, and the cement industry will be able to access them to continue producing blended cement.

(iv) Availability and access to green electricity

It is further assumed that the power sector will also achieve net-zero in line with India's commitment to be a net-zero economy. As the grid decarbonizes gradually, the emissions from electricity consumption would correspondingly come down. The Indian cement industry is expected to lead by switching to renewable energy through captive RE-based power plants or open access route in line with the existing trend.

(v) Reduction in emissions intensity

The overall emissions intensity[5] of cement sector would reduce from 0.68 tonne CO_2 per tonne cement (2020) to 0.56 tonne CO_2 per tonne cement (2030) and to 0.51 tonne CO_2 per tonne cement (2047) in the net-zero path to 2070.

(vi) Carbon capture to achieve net-zero

To achieve net-zero emissions, CCUS technologies need to be adopted on a large scale by all the cement plants. However, this will depend upon the financing options and commercial viability of such projects. It is envisaged that Indian cement industry would also pursue nature-based solutions (NbS) as a complementary lever to reach net-zero CO_2 emissions.

8.2
Cement sector Net-Zero CO_2 roadmap

It is expected that the cement-use efficiency will be playing a major role in reducing emissions from cement sector. The other decarbonization levers include increased use of SCMs, shift to cleaner fuels, improved efficiency in clinker production, and decarbonization of electricity. The cement industry would require CCUS technologies to handle the balance 25.1% of total CO_2 emissions (~ 387 million tonnes) in 2070 (Figure 27).

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5 Emissions intensity includes direct emissions from process and fuels and indirect emissions from electricity.

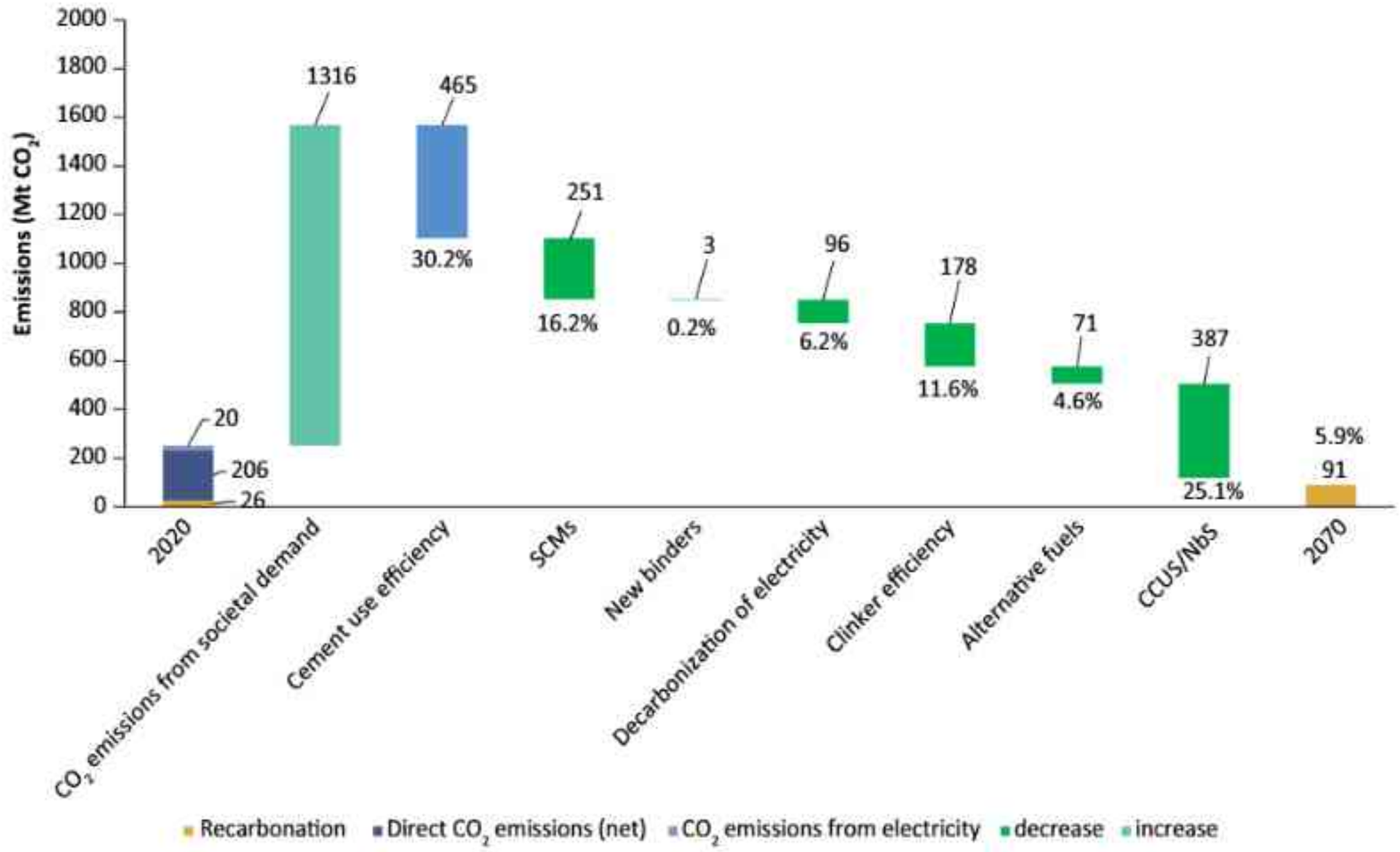

Figure 27: Decarbonization levers in Indian cement sector (2070) (Waterfall Diagram)

(i) Technology adoption matrix

The technology adoption matrix shows the likely time frames for the uptake of various decarbonization levers in the cement sector (Figure 28).

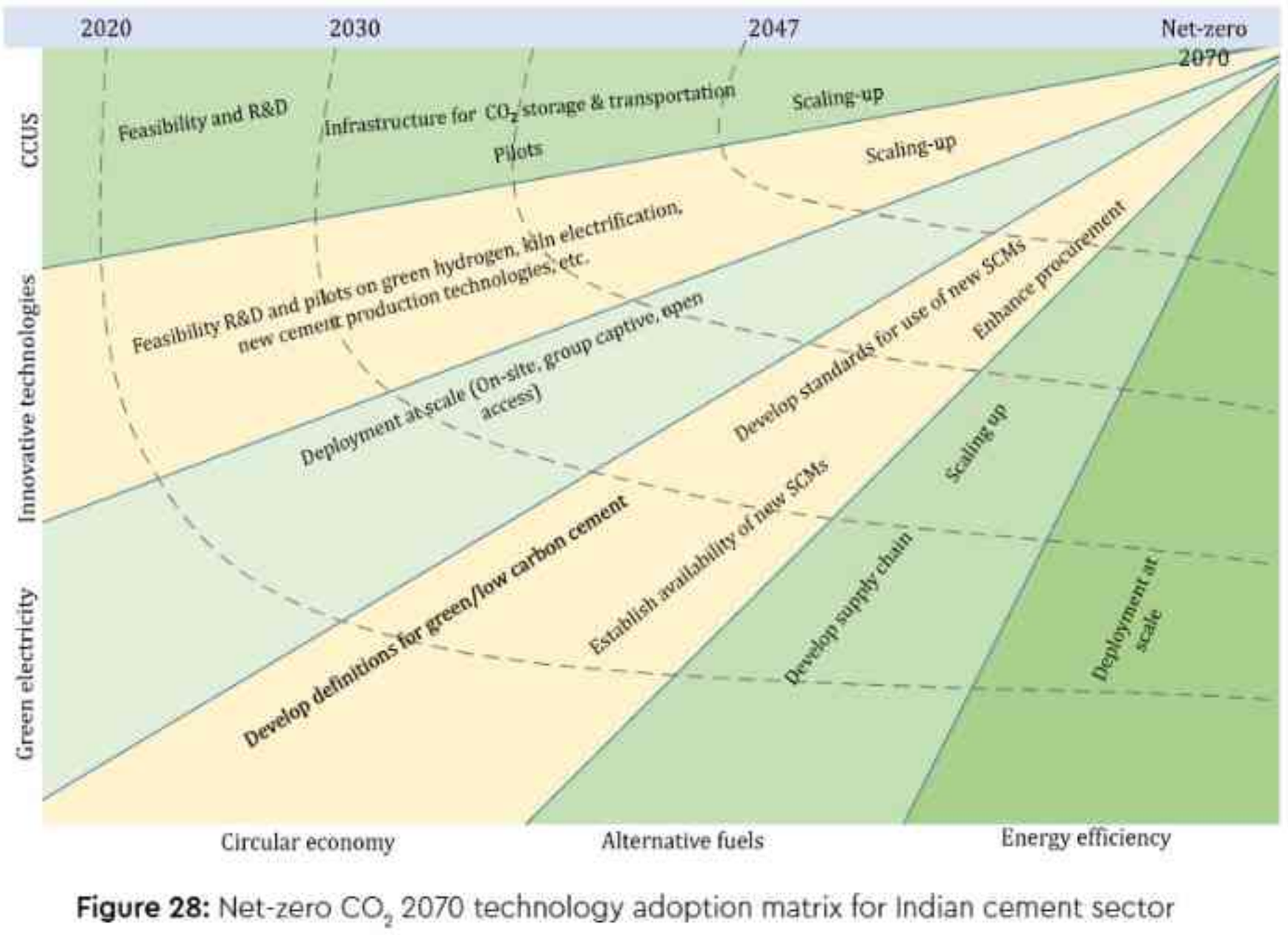

Figure 28: Net-zero CO_2 2070 technology adoption matrix for Indian cement sector

8.3
Future outlook for the cement industry

Around 23% reduction in CO_2 per tonne of cementitious material has been achieved since 1990 globally (GCCA GNR Database, 2021). The Indian cement industry is forward-looking and ready to embrace low-carbon technologies on its path to net-zero. The rate and pace of decarbonization in India in the cement sector would depend on market signals, acceptance of new cement types, availability of low-carbon fuels & technologies at affordable prices along with an enabling policy ecosystem and suitable financial instruments. The key enablers for the transition to net-zero in the cement sector are given in Figure 29.

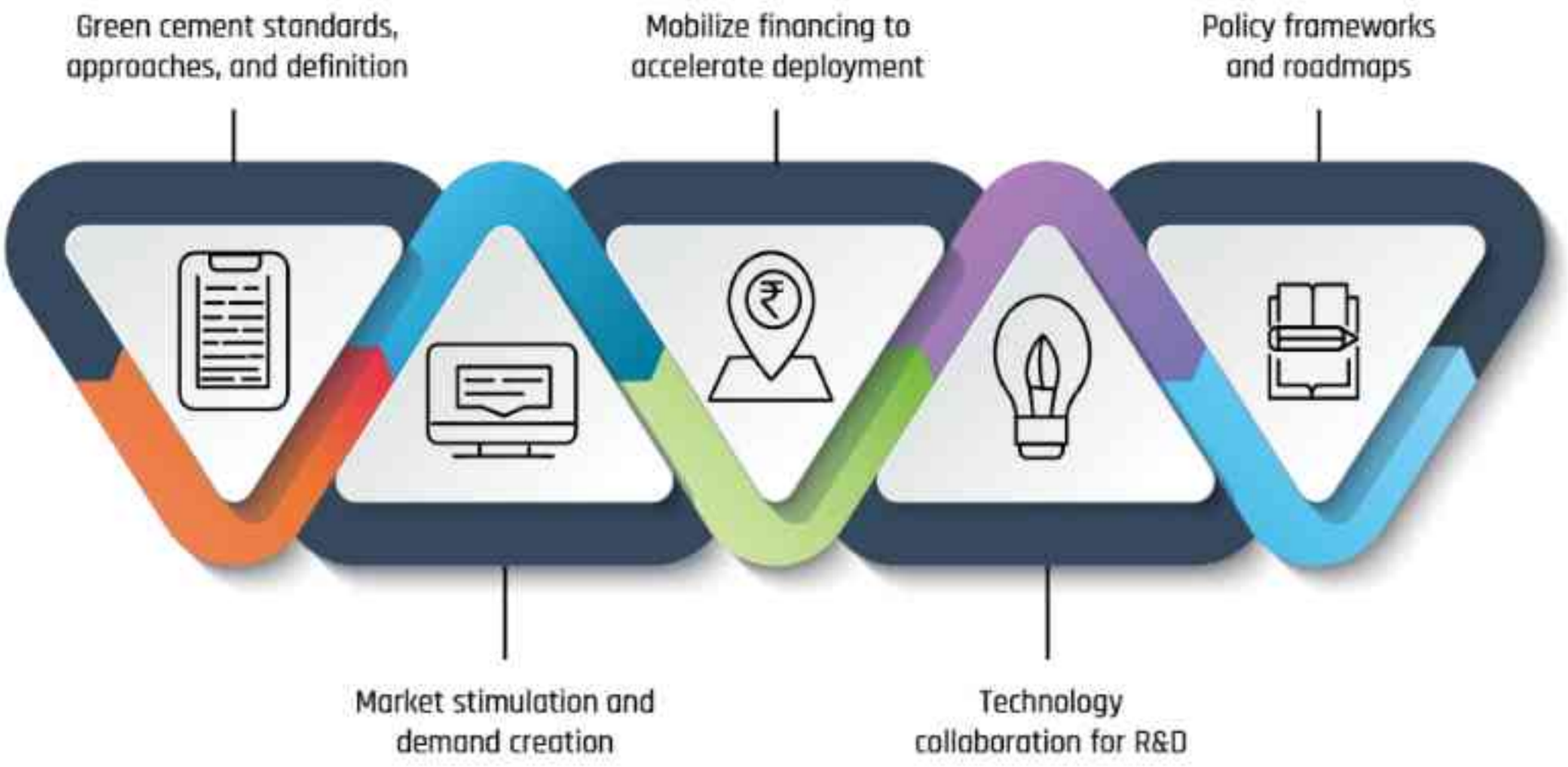

Figure 29: Key enablers to accelerate the decarbonization efforts of Indian cement industry

Decarbonizing the cement and concrete industry requires a comprehensive, multi-phased approach to policy support that addresses the varied challenges at different stages of the transition. In the near term, the industry needs policies that focus on incentivizing immediate emission reductions through adoption of available low-carbon technologies, such as energy efficient production processes and the use of alternative fuels.

In the medium to long term, policies should promote the scaling up of emerging technologies like Carbon Capture and Storage (CCS), green hydrogen use, and alternative binders while also supporting research into new materials and methods. This could involve public-private partnerships, long-term funding for R&D, and carbon pricing mechanisms that reflect the true cost of low carbon production.

The industry will need a multi-pronged focus on technology adoption, innovation acceleration and research deployment for deep decarbonization. Additionally, a harmonized global approach to standards and emission reductions will be essential to ensure competitiveness, mitigate trade risks, and drive further innovation across the sector. The policy landscape must evolve at each stage, with different tools and incentives tailored to the progress and readiness of the technology and market to deliver on decarbonization goals.

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Photograph courtesy: Cement plants of ACC Limited, Ambuja Cement, Heidelberg Materials (Werk Lengfurt), Nuvoco Vistas Corporation Ltd, J K Cement, UltraTech Cement and RMC plant of UltraTech Cement.

CEO and Leadership Messages Ratifying the Roadmap

Parth Jindal
Chair, GCCA India
Managing Director, JSW Cement Limited

The India-specific Decarbonization Roadmap for the cement sector represents a collective aspiration to achieve net-zero CO_2 emissions by 2070, aligning with the Government of India's goals. Developed collaboratively with Industry and other stakeholders, it lays out pathways to accelerate transition, and innovate and adopt advanced and new technologies. This roadmap symbolizes the sector's commitment to sustainable practices, economic growth, and climate action, serving as a guiding framework to decarbonize and build a resilient, greener future for India.

Deepak Khetrapal
Co-Chair, GCCA India
Manging Director and CEO, Orient Cement Limited

The release of the Decarbonization Roadmap of the Indian cement sector (Net zero CO_2 by 2070) is a pivotal event for our industry, the built environment and our blue planet, our only home. Cement and concrete are the essential building materials critical to providing habitable, affordable, safe, and comfortable living spaces for our fellow humans and for building the sustainable world of tomorrow. These essential materials play a vital role in addressing the need for sustainable, prosperous and resilient communities through the delivery of key infrastructure, housing, drinking water, and energy. Our Decarbonization Roadmap shows the aspiration of the industry, demonstrating how it can be decarbonized and fully contribute to a net zero world in alignment with the commitment of the Government of India.

Joydeep Mukherjee
Co-Chair, GCCA India
Managing Director, HeidelbergCement India Limited

Let's come together in the fight against climate change and commit to achieving a 'net zero' future. By embracing the sustainable practices outlined in the Decarbonization Roadmap for the Indian Cement Industry, we can make significant strides towards reducing our carbon footprint. I strongly urge individuals, businesses, and governments to prioritize collaborative action, working hand-in-hand to drive innovation and implement solutions that create a lasting, positive impact on our environment. Together, we have the power to drive meaningful change and shape a sustainable future for generations to come.

Ajay Kapur
CEO and Whole Time Director
Ambuja Cement Limited & ACC Limited

The release of the GCCA India Decarbonization Roadmap for the Cement Sector marks a pivotal moment in the cement industry's journey towards sustainability. With this roadmap, we reaffirm our commitment to achieving net-zero CO_2 emissions well before 2070 while aligning with India's net-zero emissions targets. We have been pioneers in sustainability, being the first Indian cement company to announce science-based Net Zero targets, first in the world to be signatory to IRENA's Alliance for Industry Decarbonization (AFID) as well as a member of the United Nations Global Compact (UNGC). By establishing new benchmarks, adopting advanced technologies, fostering digitalization and cultivating innovation mindset, we are taking concrete steps to decarbonize our value chain while fuelling the nation's growth through infrastructure development.

Sandip Ghose
Managing Director & Chief Executive Officer
Birla Corporation Limited

Cement is one of the most important building material having carbon footprint. Proposed decarbonization roadmap outlines a clear path to net-zero emissions, combining both traditional levers (increased use of SCMs, thermal efficiency, decarbonizing electricity) and modern levers (CCU & CCUS). At Birla Corporation Limited, we are decreasing our carbon footprint by maximizing SCM use, adopting alternative fuels, expanding renewable energy, and operating efficient waste heat recovery systems. These efforts along the lines of the roadmap will help us to reach net-zero goals.

Mahendra Singhi
Member of Board of Directors & Strategic Advisor
Dalmia Cement (Bharat) Limited

Achieving net zero in the Indian cement sector demands a synergistic approach, where advanced technologies enhance efficiency, policy frameworks incentivize green innovation, and finance seamlessly supports transformative solutions. Together, these levers can unlock the sector's immense potential to decarbonize while fostering the sustainable growth of India's infrastructure. I am confident that a proactive approach to developing a decarbonization roadmap will ensure the timely achievement of global ambitions.

Arun Kumar Shukla
President & Director
JK Lakshmi Cement Limited

As we stand at a pivotal moment in the fight against climate change, India's journey towards achieving Net Zero by 2070 is both a challenge and an opportunity. In line with the same vision of our Government of being net zero we as Indian cement industry have also taken the target of becoming net zero by 2070 and being the member of GCCA-India we take this opportunity of finalizing the net zero roadmap for Indian Cement industry voluntarily. We are committed to adopting sustainable practices that not only help us reduce our carbon footprint but also contribute to the broader goal of Net Zero emissions. This involves embracing renewable energy, alternative fuel and raw materials, enhancing the production of blended cement to reduce clinker consumption, driving innovations in energy efficiency, and working hand-in-hand with our partners, stakeholders, and communities to foster a green and resilient economy.

Madhavkrishna Singhania
Joint Managing Director and CEO
JK Cement Limited

As a responsible corporate, we at JK Cement are steadfast in our commitment to the decarbonization goals set forth in the roadmap. Aligned with India's commitments under the Paris Agreement, sustainability lies at the core of our operations. We are currently utilizing 50% renewable energy and have set an ambitious target to achieve 75% by 2030. Our ongoing initiatives are further reinforcing our dedication to sustainable practices. We remain committed to achieving net-zero emissions by 2070, contributing to India's climate goals, and building a greener, more sustainable future.

J Ranjith Rao
Managing Director
My Home Industries Limited

Scientifically, it is well established that the climate change and its adverse effects are real and they are going to affect the entire planet as seen across the world. Cement and concrete are the most widely consumed man-made materials on Earth. In addition to this, Cement & Concrete industry consumes highest natural resources. We recognize that the cement sector is hard to abate due to CO_2 emissions coming from the raw material in large quantities unlike all other sectors. The Indian Cement Sector is the most energy efficient and has lowest CO_2 intensity in the world. The net zero India roadmap developed by the Indian cement and concrete sector by 2070 is positive vision document taking into consideration all de-carbonization levers in the value chain. It also addresses the technological, policy and financial challenges in the short, medium and long term. With the support of the Govt. of India and all other stakeholders, I am extremely confident that the net zero ambition of the country aligning with global ambition of sustainable planet will be achieved.

Jayakumar Krishnaswamy
Managing Director
Nuvoco Vistas Corp. Limited

As a cornerstone of infrastructure development, the building materials industry holds a significant responsibility to mitigate its carbon footprint and adopt sustainable practices.
The decarbonization roadmap guides the sector towards innovative solutions such as alternative raw materials, low-carbon technologies, and renewable energy to combat climate change.
Collectively, the cement industry can achieve net-zero carbon and drive sustainable growth.

A V Dharmakrishnan
Chief Executive Officer
Ramco Cements Limited

At Ramco, environmental sustainability is central to our business strategy. The Decarbonization Roadmap reflects our collective aspiration to achieve net zero CO_2 emissions by 2070, supported by effective government policies and financial mechanisms. We aim to reduce our carbon footprint and preserve biodiversity through decisive actions and collaborative efforts, in line with the roadmap and our aspiration to reach net zero.

S Sreekanth Reddy
Joint Managing Director
Sagar Cements Limited

It gives me immense pleasure to welcome the GCCA India Net Zero CO_2 roadmap. At Sagar Cements, we believe this is a step in the right direction. GCCA roadmap will showcase industry's commitment and define the levers for decarbonization, both essential to bring meaningful change. Sagar Cements has been contributing to the development of economic, environmental and social capital of the nation. We have committed to Net Zero by 2050 and validated our GHG emission reduction targets. We are making the best efforts to reduce our carbon footprint. The implementation of the roadmap might need collective efforts of industry, research, academia, government, and civil society. The collaboration, coupled with dedicated finance and technological advancements, is vital. I am looking forward to witnessing significant progress in these areas in the near future.

R Krishna Kumar
Chief Executive Officer and Managing Director
Shree Digvijay Cement Limited

Shree Digvijay Cement Company Limited is committed to achieving net zero CO_2 target as part of its broader sustainability goals. The company has outlined several key initiatives and strategies to reduce its carbon footprint and promote eco-efficiency in its operations, viz., investing in advanced technologies to improve energy efficiency in its cement production processes which includes optimizing kiln operations and utilizing waste heat recovery systems to reduce energy consumption, usage of alternate fuels, usage of renewable energy besides producing blended cements that have lower environmental impact.

K C Jhanwar
Managing Director
UltraTech Cement Limited

As a steadfast partner to India's growth story, the cement industry is continuously working towards reducing its environmental impact. The Decarbonization Roadmap for the Indian Cement Sector will set the direction for sustainable growth and address the challenges of carbon intensity reduction in the cement industry.

A Net Zero Roadmap specific to the Indian cement industry will help it follow several key pathways, such as improving energy efficiency, adopting clean energy sources, and innovating manufacturing processes, helping shape the journey towards a sustainable future with a clear vision. As a founding member of Global Cement and Concrete Association, UltraTech is proud to collaborate with GCCA India on the Decarbonization Roadmap and strives to accelerate the decarbonization of its operations.

Stakeholder Ratification

Dr Martin Schneider
Managing Director
European Cement Research Academy

Congratulations to the Indian cement industry for finalizing its roadmap to net-zero CO_2. As ECRA, we are pleased to have had the opportunity to support our Indian colleagues in developing the various pathways to decarbonize cement and concrete. We all know that greenhouse gases should be reduced as fast as possible and, in this context, the target year of 2070 for the Indian roadmap is in line with the GOI's aspirations to reduce its CO_2 emissions. This is certainly a significant milestone in the history of the Indian cement and concrete industry, especially considering the huge and growing demand for building materials in India over the coming decades. We are confident that the enormous capacity of our Indian colleagues and their high level of technical expertise are the basis for an efficient and successful transformation. Whether the pace of implementation of the net-zero targets can even be accelerated will largely depend on the boundary conditions addressed in the Roadmap.

The Indian cement industry can be proud of its Roadmap, which provides the ideal basis for a decarbonized cement and concrete value chain. We wish our Indian friends all the best as they now embark on the implementation of the various pathways.

Dr Shashank Bishnoi
Professor, IIT Delhi
Head of LC3-TRC Asia
LC3 Technology Research Centre

As the development of infrastructure in India continues at a rapid pace, the emission reductions achieved by the industry will have a major impact on global emissions. This document provides the industry with the means to meet its sustainability targets while meeting the development aspirations of the nation. As a researcher, I also hope that new developments and innovations made in India and for India will support the needs of the industry to achieve and surpass the targets highlighted in this document.

Per Andersson
Head of LeadIT Secretariat
Leadership Group for Industry Transition (LeadIT)

This roadmap presents a tailored approach to decarbonizing the Indian cement sector, shaped by industry leaders and LeadIT members who are already taking bold steps towards a low-carbon future. As India moves towards its Viksit Bharat 2047 vision and beyond, the cement industry is poised to play a pivotal role in the green transition and the decarbonization efforts in India. In turn, this can set an example for others worldwide and contribute to cutting global emissions significantly.

Vijaykumar R Kulkarni
Founder-Director,
Low Carbon Construct Forum (LCCF)

Low Carbon Construct Forum (LCCF) whole-heartedly welcomed the joint efforts of GCCA-TERI to evolve the Net Zero Roadmap for the Indian cement and concrete industries and participated in the meetings of their Task Force as a subject matter expert.

There has been an urgent need for an India-specific low carbon roadmap for the Indian cement and concrete industries. Considerable deliberations happened in the Task Force meetings to evolve the specific levers to achieve the objectives. We are sure that the follow-up actions to achieve the targets suggested in the levers would go a long way in the transformation of the Indian cement and concrete industries on the low carbon pathway.

A K Jain
Principal Consultant
Ready Mixed Concrete Manufacturers' Association (RMCMA)

Climate Change and sustainability of natural resources are critical concerns today for survival of life on earth. Efforts of GCCA, TERI and Indian Concrete Industry are highly commendable to achieve zero net CO_2 in production of cement in India by 2070. I wish all the organizations grand success in achieving the noble target.

Sivaram Krishnamoorthy
Director Industry
SED Fund

Cement Industry in India was one of the earliest GHG intensive sectors to have come out with a public GHG roadmap for itself voluntarily as early as 2012 envisaging an ambitious pathway of 45% reduction GHG intensity by 2050 as compared to 2010. This catalysed various initiatives both by individual companies and at a sector level over the last 15 years, despite even the various mergers and acquisitions which took place.

The national level net zero commitment by 2070 can be fulfilled only with the buy in, support and commitment from industry especially the GHG intensive ones. Global Philanthropic donor community and the SED fund looks forward to working with the GCCA India, its member companies and other stakeholders in terms of implementation as well as towards catalysing similar initiatives that take a solutions-oriented approach towards Industry decarbonization and an equitable energy transition.

Notes

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About GCCA India

Global Cement & Concrete Association (GCCA) India works with the Indian cement & concrete sector on climate change, circular economy, health & safety, SDGs and communication. GCCA India covers close to 80% of India's cement capacity. Sustainable development of the cement and concrete industry is at the core of the GCCA's work.

The GCCA gathers and publishes data on the industry's sustainability commitments, guidelines, and initiating research. 'Decarbonization Roadmap for the Indian Cement Sector: Net-Zero CO_2 by 2070' is the collective aspiration of India's leading cement companies to contribute to building the sustainable world of tomorrow.

More information about GCCA is available at https://gccassociation.org/

ACC

Ambuja Cement

BIRLA CORPORATION LIMITED
MP BIRLA GROUP

Dalmia cement

HEIDELBERGCEMENT

India Cements

JKcement

JK LAKSHMI CEMENT Ltd.

JSW Cement
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MAHA CEMENT
BUILD IT STRONG

NUVOCO
Shaping a new world

ORIENT CEMENT

THE RAMCO CEMENTS LIMITED
RAMCO

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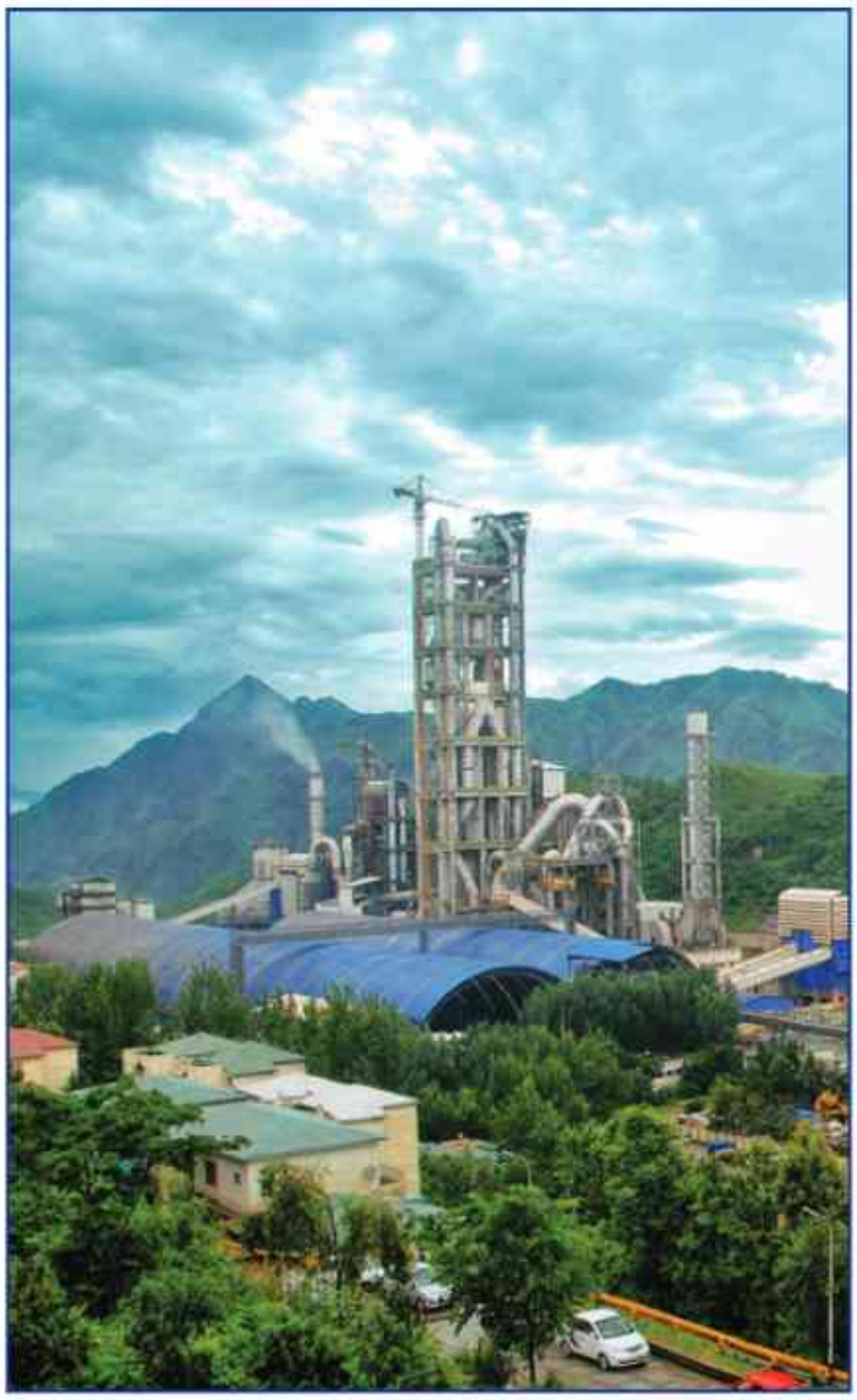

Global Cement and Concrete Association
India

91 Springboard, Godrej & Boyce, Gate no. 2B, Plant 6,
LBS Marg Vikhroli (West), Mumbai – 400079, India

indiacommunications@gccassociation.org

https://www.linkedin.com/company/gccaindia/

https://twitter.com/theGCCAIndia